

COMPLETE REPORT

of

J. J. de KINDER

On the

Vosmaer System of Producing
Ozone for the Purification of
Water and other purposes.

Owned by

The United
Water Improvement Company

PENNSYLVANIA BUILDING, PHILADELPHIA

PHILADELPHIA

GEORGE H BUCHANAN COMPANY

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Report of Investigations and Result of same made at Nieuwersluis, Holland, of Water Sterilization by Ozone

System, A. VOSMAER

DESCRIPTION OF PLANT:

The plant consists of :

- (a) A steam boiler ;
- (b) Air drying tank ;
- (c) Krönke rough filter ;
- (d) Standpipe ;
- (e) Ozonizer ;
- (f) Water-pump ;
- (g) Airpump ;
- (h) Alternating current generator ;
- (i) Step-up transformer with switchboard and a special condenser, with all necessary piping and wiring, the whole covering a ground space of about 20 x 40 feet independent of the adjoining laboratory, which covers a space of about 10 x 15 feet.

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CAPACITY :

The water ozonizing capacity of the plant is equal to 20 cubic meters per hour, or, in round numbers, 5300 gallons.

LOCATION :

The plant is located at Nieuwersluis, on the River Vecht, between the cities of Amsterdam and Utrecht.

The "Vecht" is a small stream which is fed from the River Rhine below, and moves either slowly towards the Zuyder Zee, or is checked entirely when the tide in the Zuyder Zee is high. It is one of the most polluted waters in Holland, inasmuch as the city of Utrecht, and all of the great many smaller towns and villages along its borders, as well as numerous factories, laundries, etc., use it as a common drain; besides a very large surface of Polder land empties its waters into it, and, hence Vecht water contains a high percentage of soluble organic matter at all times, and a remarkably high percentage after heavy rains.

GENERAL OPERATION :

The water to be ozonized is conveyed by means of a pump from the Vecht to a Krönke rough filter, and from there to the top of a standpipe, having a diameter of 15 inches and a height of 35 feet, down which standpipe it flows on its way to the receiving reservoir located outside of the building.

Air is drawn by means of an airpump from an iron tank in which are compartments or shelves upon which chloride of calcium has been charged and issues from the tank in a dry state, the chloride of calcium having absorbed the moisture which it contained before entering the tank.

On its way to the suction side of the pump the air passes through the ozonizer, an apparatus consisting of a

number of light copper tubes, each about three (3) inches in diameter and sixteen (16) feet in length, the tubes being supported at either end in headers (in the manner of an ordinary closed feed water heater), the air discharge pipe from the drying tank connecting with the header at one end of the ozonizer, and the air suction pipe to the airpump with the opposite header of the ozonizer. The pump compresses the air to slightly above atmospheric pressure and delivers it in the bottom of the standpipe already referred to in which it ascends, distributing itself in minute globules through the descending water.

In the ozonizer, the air in passing through the tubes is ozonized by means of a SILENT ELECTRIC DISCHARGE.

An ordinary generator delivers its alternating current to a switchboard, from whence it goes to a step-up transformer and from here to the dischargers which are located in the tubes.

There is nothing out of the ordinary about the transformer or any other part of the electrical apparatus, with the exception of the condenser (A. Vosmaer patent), which is of special design. From one and one-half to two grams of ozone (O_3) per cubic meter of water pumped are used, and the electrical energy required to produce one gram of ozone is about 60 watts (one kilowatt hour producing about 15 grams of ozone), and the quantity of ozonized air required for the ozonizing of the water is in proportion of about one and eight-tenths volumes of atmospheric air to one volume of water.

Upon my arrival at Nieuwersluis on February 4, 1904, I placed myself in communication with the inventor, Mr. A. Vosmaer, and with Dr. A. Lebret, the well-known bacteriologist in charge of the bacteriological department of the ozone company (Ozone-Maatchappy, System, A. Vosmaer), and preparations were at once made for examining every detail of the plant, and for making tests under different con-

ditions of quantities and qualities of water supply, etc., the results of which are shown in the following table:

Experiments Carried Out at the Nieuwersluis Plant with Rough Filtered Water.

DATE Feb.	Water per Hour in Cu. Meters	Ozonized Air per Hour in Cubic Meters.	Ozone in Grams per Cu. Meters	Total Ozone in Grams	Ozone per Cubic Meter of Water in Grams	Electric Energy in Watts	Number of Bacteria per Cubic Cen- timeter after Three Days' Incuba- tion at 20° C.			Organic Matter in Solu- tion. Milligram of Per- manganate of Potassium to Oxidize	Before Ozonization	After Ozonization	Per Cent. of Re- duction
							Raw Water	Sample 1	Sample 2	Sample 3			
8	5	16.8	1.6	26.88	5.38	1,800	85,500	1	2	3	22.6	17.3	23.2
9	5	16.8	1.6	26.88	5.38	1,800	43,300	0	2	0	—	—	—
10	7.5	16.8	1.6	26.88	3.58	1,800	68,400	1	1	1	—	—	—
11	7.5	16.8	1.6	26.88	3.58	1,800	30,000	8	5	—	19.1	14.25	25.7
12	10	16.8	1.6	26.88	2.69	1,800	56,000	8	11	7	18.9	14.2	24.7
13	15	16.8	1.6	26.88	1.79	1,800	42,000	63	41	57	24.3	21.9	10

REMARKS—1 cubic meter equals + 270 gallons.
Evidently 15 cubic meters per hour was too much to be taken care of by 1800 watts; the too low reduction in organic matter shows this at once.

The mechanical operation of the plant was in charge of the regular engineer, while the bacteriological observations were in charge of Dr. Lebret, samples of water for bacteriological tests and all observations being taken in my presence.

“From a paper read by Mr. Vosmaer before the Society of Hydraulic Engineers of Holland, convened at 's-Gravenhage on September 12 and 13, 1903, on the sterilization of water by the use of ozone, a translation of which follows:

Translated from the Report of the Fourth Convention of the Society of Hydraulic Engineers of Holland, convened at 's-Gravenhage, on September 12 and 13, 1902.”

The Sterilization of Water by the Use of Ozone

BY A. VOSMAER.

Gentlemen—About two years ago I had an opportunity to discuss before you the question of ozone production, but at that time I was compelled to limit the discussion to the question of production only, not being able then to elaborate the subject of sterilizing water by ozone, inasmuch as there was not at our laboratory in Haarlem opportunity to apply it to the purpose of sterilizing water, and as a matter of fact the question of the manufacture of ozone is and remains the principal one, because all speculations in regard to water sterilization by ozone amount to nothing unless ozone can be manufactured on a sufficiently large scale to make it applicable.

Two years ago I necessarily limited myself to the discussion of other systems, saying little about our own. (See sterilization of drinking water by ozone in *De Ingenieur*, organ of the Society of Civil Engineers of Holland, 2d and 9th of September, 1899, Nos. 35 and 36.) But we are now able to consider our system, because it has been thoroughly tested. It is not my intention, therefore, to lecture on the question of ozone sterilization, inasmuch as I would have to weary you with repetitions. No doubt the publications of Siemens & Halske are known to you, and you are, no doubt, acquainted with their method of original operation with tubular apparatus. The first publication of Dr. Erlwein in

1901 covered apparatus with glass plates, while the installation at Wiesbaden in 1902 again involved the original idea from which it is justifiable to conclude that the change from tubular apparatus to plates was not a lasting improvement.

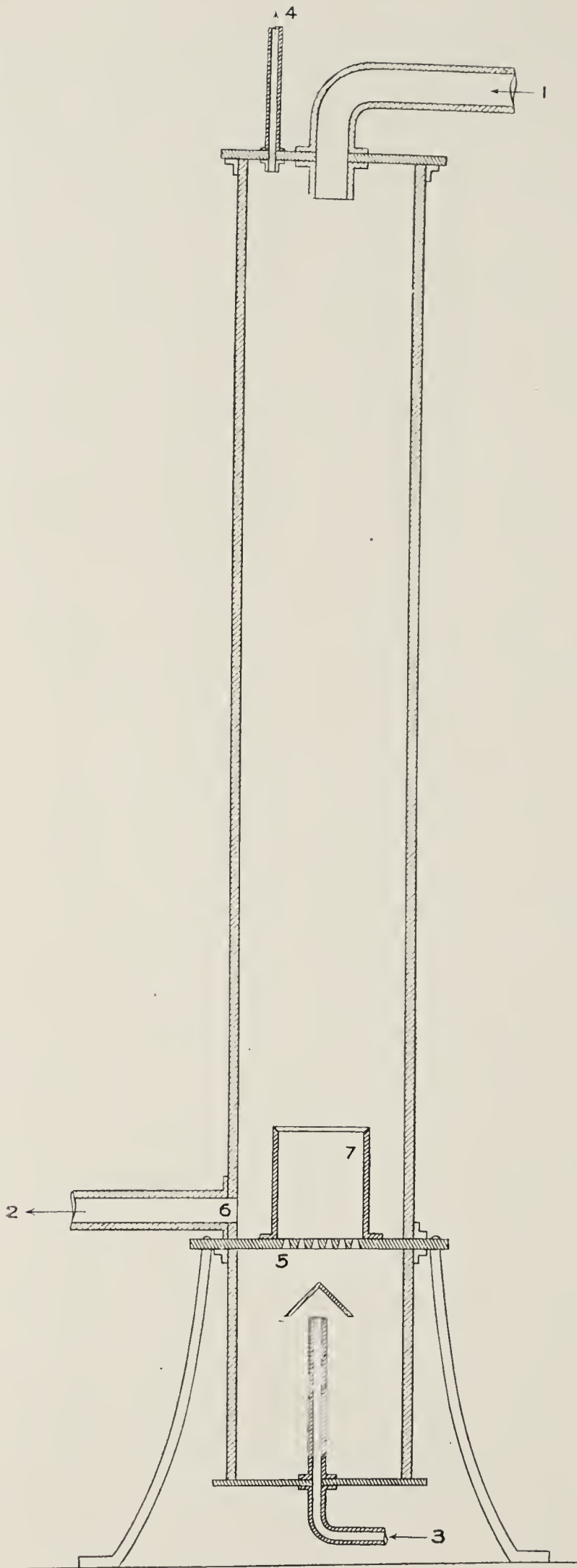
In the technical arrangement of our apparatus we have aimed, first of all, to secure absolute reliability and extreme simplicity, and in this we have completely succeeded, although at the expense of a slight economical loss in quantity of production. The apparatus of Siemens & Halske produces a larger quantity per unit. The production in grams of ozone per kilowatt hour is greater than in our system, but whereas they attempt to secure reliability (in Wiesbaden) by the application of a number of controlling and danger signals we have secured absolute reliability through another system, viz: through the absence of all dielectrics.

In our apparatus there is no mica or glass upon neither of which reliance can be placed, and our special electrical arrangement prevents absolutely the creation of the dangerous arc discharges. It is, therefore, a matter of personal opinion whether it is more advantageous to have absolute reliability with a somewhat more expensive apparatus than non-reliability with a somewhat cheaper one. Both systems, therefore, have their advantages and disadvantages. Our ozone apparatus, which many of you have seen at work at Schiedam, has been much simplified and been reduced to one-tenth of its size for the same production. The system, however, has remained the same, only the technical arrangement as now in existence at Nieuwersluis is simplicity itself, but inasmuch as the apparatus has worked at Schiedam and at Nieuwersluis without any interruption of the slightest kind day in and day out with constant results, it is not necessary to discuss the question of reliability any further. We are making our apparatus for twenty-four hours' work per day and guarantee its reliability. The reason why I emphasize the question of reliability so strongly is because it is just in this reliability that our strength lies and which justifies our claim

of superiority over any other apparatus for which a claim of higher production per unit may be made.

But I desire to call your attention to the subject of sterilization of water, and in particular to the results which we have obtained at Schiedam and Nieuwersluis. When the City government of Schiedam asked us for figures for an ozone installation and its cost per cubic meter of water treated, we requested permission to erect our plant at Schiedam in order that we might have an opportunity to thoroughly test it, inasmuch as this could not be readily done at Haarlem. This request was granted and in consequence we were able to operate the apparatus for two and one-half consecutive years at Schiedam. Following in the footsteps of Tyndall we contented ourselves during the first half year and during part of the second half year by operating the sterilizer in accordance with Tyndall's system, viz: entering the ozone into the water in the direction of the latter's flow. The results obtained were not satisfactory, and although we operated just as Tyndall did in Brussels, viz: with 20 cubic meters of water per hour and 40 liters of ozone of $3\frac{1}{2}$ grams O_3 per cubic meter the bacteriological results were not satisfactory. This induced us, inasmuch as our system of ozone making was the reverse of that employed by Tyndall, to reverse the operation of sterilization also and not to attach any value to Tyndall's publications, and from the moment that we introduced a sterilizer on the principle of countercurrent our success was assured. The sterilizer is arranged as follows: (See accompanying figure.)

The water enters at 1 and passes out at 2, while the ozone enters underneath at 3 and passes out at 4 (or rather the air passes out at 4) for at that point the ozone has completed its work and is again changed to oxygen, or what was not ozone escapes into the atmosphere. The apparatus works continuously and entirely as countercurrent apparatus, which is naturally the most economical: A peculiar construction of the lower part makes it impossible for the water to enter



into the ozone supply, and prevents the ozone from passing out with the water. The first is obtained by the presence of the perforated plate 5. So long as there is sufficient pressure water cannot possibly pass, on the principle of the bottom of a Bessmer converter. The second is obtained by the presence of the perforated wall 6 and the screen 7. Our sterilizer has a capacity of from 20 to 30 cubic meters per hour, a diameter of 30 centimeters (12'') and a height of a little over 10 meters (34'). You are all acquainted with the fact that technically counter-current apparatus are the most economical, and that is just the case here. A single example is sufficient to prove this. According to the reports of Siemens & Halske, to whom further reference will be made, they used for the purpose

of ozonizing one cubic meter of water + two and one-half grams of ozone, whereas we hardly need one gram because of our perfect sterilizer. Ozone does not affect bacteria by absorption. Absorption apparatus are, therefore, not advantageous, because there the intention is to distribute a maximum quantity of gas through a minimum quantity of liquid, while in ozonization a maximum quantity of water must be treated with a minimum quantity of ozone. The economical results are there to prove this.

I will now proceed to show what results we have obtained with our apparatus. In Schiedam they had water twice filtered; first, through coarse sand, and afterward through dune sand. We were asked to treat with ozone the water that had been filtered once. The purpose was, therefore, to substitute ozonization for the second filtration. The first filtered water, which was very good, contained, according to Dr. 't Hoff, from 200 to 1000 bacteria per cubic centimeter, sometimes less than 200. After ozonization the following figures were obtained.

Results.

Date	2	3	4	5	7	8	9	10	11	16	17	18
10 M. . . . {	0 1	0 0	0 1	0 2	0 0	1 1	1 1	0 0	1 1	1 0	2 1	5 1
15 M. . . . {	1 0	2 0	0 0	0 1	0 0	5 0	1 0	3 1	2 1	3 1	2 1	5 2
20 M. . . . {	2 2	3 0	0 0	1 0	2 1	0 4	0 4	1 0	0 0	4 4	2 1	2 1

In this table of two weeks' run the figures given represent the number of bacteria left after ozonization.

It represents three series, viz: The ozonization of 10 cubic meters (+ 2700 gallons), 15 cubic meters (+ 4050 gallons), and 20 cubic meters (+ 5400 gallons) water per hour, with one and the same amount of energy expended for making the ozone, viz., 2 kw.

This is a very good result compared with the table of Siemens & Halske, where it is true the number of bacteria was larger, but where instead $2\frac{1}{2}$ grams of ozone were used per cubic meter. We were working, however, under more

favorable conditions, inasmuch as the water had been once filtered, while Siemens & Halske worked with rough filtered water. In our case, therefore, because the ozonization was supplementary to that of filtration we obtained better water, but at a greater expense. We desired, however, to apply the ozonization just as Siemens & Halske did—as a substitute for filtration—and decided, therefore, to transfer the installation to Nieuwersluis, because the water from the Vecht is of worse quality than that of the Maas. Besides, this Vecht water is not filtered (so called) but merely rough filtered by a plain mechanical filter (system, Krönke). Whereas in an ordinary filter the speed of filtration is something like 100 millimeters per hour (4") in this case, viz: with the Krönke rough filter the speed was 4000 (40") millimeters per hour. When the filter has worked for one day it is stopped and the current reversed, while the drum is made to revolve, by which operation the sand in the drum is cleaned. There is, therefore, no question of any biological effect and it involves simply mechanical filtration or sifting of matter in suspension. That more ozone would be required for the ozonization of this mechanically filtered Vecht water than for the Schiedam water was to be expected. We limited ourselves not to 10, 15 and 20, but to 5, 10 and 15 cubic meters of water per hour with the following results:

Treatment of 15 Cubic Meters (+ 4050 Gallons) per Hour

Date	Serial Number of Experiments (9 each day)									Average	Number of Bacteria in Raw Water	Organic Matter in Solu- tion in Raw Water in Milligram Permanga- nate of Potassium	Per Cent. of Reduction in Organic Matter
	1	2	3	4	5	6	7	8	9				
Aug. 4	38	35	49	11	13	13	18	12	21	23	6,860	1.11	26
" 5	21	28	23	14	23	24	14	15	19	20	4,410	10.1	25
" 7	23	29	16	12	10	11	15	14	12	16	4,770	10.3	20
" 8	11	15	6	13	6	10	11	14	12	11	5,590	10.7	24
" 9	5	4	5	5	5	4	4	11	5	5	4,050	10.8	20
Average										15			

Treatment of 10 Cubic Meters ($\pm$ 2700 Gallons) per Hour

Date	Serial Number of Experiments (9 each day)									Average	Number of Bacteria in Raw Water	Organic Matter in Solu- tion in Raw Water in Milligram Permanga- nate of Potassium	Per Cent. of Reduction in Organic Matter
	1	2	3	4	5	6	7	8	9				
July 7	14	4	10	7	5	19	7	8	9	9	2,300	11.3	30
" 8	10	13	4	4	6	2	9	5	7	7	2,400	11.3	26
" 10	9	8	9	5	7	10	7	4	6	7	1,960	11.2	26
" 11	16	—	—	8	10	7	15	12	23	13	1,670	10.9	23
" 15	6	10	4	3	5	—	8	4	6	6	4,950	10.3	26
" 16	7	8	10	5	8	6	3	5	10	7	950	10.1	31
" 17	9	7	10	1	3	10	2	3	11	6	920	9.9	28
" 18	10	8	4	6	4	2	—	—	—	6	800	9.8	23
" 19	2	2	7	3	2	2	7	3	3	3	880	9.2	17
" 21	0	1	1	6	0	1	—	—	—	1	550	8	39
" 25	14	16	9	6	11	9	3	9	7	9	3,800	9	22
Average										7			

Treatment of 5 Cubic Meters ($\pm$ 1350 Gallons) per Hour

Date	Serial Number of Experiments (9 each day)									Average	Number of Bacteria in Raw Water	Organic Matter in Solu- tion in Raw Water in Milligram Permanga- nate of Potassium	Per Cent. of Reduction in Organic Matter
	1	2	3	4	5	6	7	8	9				
July 26	4	2	3	2	3	3	2	3	2	3	5,150	9.5	40
" 28	8	0	6	2	2	0	1	0	1	2	20,160	9.5	36
" 29	1	0	2	1	1	2	0	1	0	1	705	8.4	45
" 30	1	5	2	2	1	1	1	1	1	2	1,730	9.2	43
" 31	1	2	0	1	1	0	1	1	0	1	1,920	8.5	40
Aug. 1	1	1	0	2	1	1	0	4	1	1	1,400	10.5	32
" 6	1	1	4	0	2	0	—	—	—	1	1,700	10.0	44
Average										2			

The raw water varies in number of bacteria from 700 to 20,000 per cubic centimeter. The Vecht is rather more of a ditch than a river. It receives a great deal of Polder water and after heavy rains the number of bacteria is raised to over 40,000 and often to over 70,000 per cubic centimeter, while in very dry weather the number is reduced to under 700. The original number of bacteria has, however, little effect on the result obtained by ozonization. To complete the table I have added the status of organic matter. When instead of 5 cubic meters we take 15 cubic meters we obtain a less favorable bacteriological result, as might be expected. In the meantime I became acquainted with what is said in a publication of *Kaiserliche Gesundheitsamt*, wherein Dr. Ohlmüller and Dr. Prall furnished a report on the "Die Behandlung der Trinkwassers mit Ozon" (the treatment of water with ozone). This publication was made by authority of the government, and has, therefore, the unquestionable stamp of reliability and impartiality. In the article referred to, we find among others the following observations:

[Translated from the German.]

"It would be an unjustified requirement to ask that a water ozonizing plant should furnish water absolutely free from all bacteria. In no known arrangement of central water purification is this condition aimed at, nor is it necessary considered from a hygienic point of view, etc." (See *Arbeiten Gesundheitsamt*, Band 8, p. 159.) A reduction of bacteria to 100 per cubic centimeter is considered sufficient. This result is readily obtained by ozonization by which the bacteria (in Spree water), after the latter having been rough filtered through a Krönke filter to arrest the material in suspension, was reduced from 83,700-86,800 to 20-28.

A verdict like this, considering the origin, allows us to confine ourselves to aiming not at complete sterilization, but at nearly complete sterilization with absolute safety; but the great question, of course, is this: *Those 20 bacteria*

which are left over—what are they? May they not be the most dangerous ones? Although it was well known through experiments on a small scale that pathogenic bacteria or disease germs offer feeble resistance and are easily killed, Drs. Ohlmüller and Prall experimented on a large scale, viz: with 10 cubic meters of water per hour after infecting the water with the bacilli of typhus and cholera, viz: the water contained $\pm$ 17,000 cholera bacilli per cubic centimeter, 35,000 typhus bacilli and 33,000 coli bacilli. Twenty-four tests were made and in all 24 *sterile* results were obtained—not entirely satisfied yet, they mixed infected water with ordinary Spree water 1 to 1. Before the ozonization the total was 43,800 to 45,107 per cubic centimeter, after the ozonization 5 and 6. “In dem nicht ozonisirten wasser könnten die cholerabakterien nachgewiesen werden, in dem ozonisirten waren sie vernichtet” (“in the water not ozonized the cholera bacteria could be detected; in the ozonized water they were destroyed”). The same tests were made on a larger scale, with the result that ozonization reduced the number of bacteria from 38,330-16,590 to 8-9, respectively, hence their verdict.

These investigations proved that the treatment of water with ozone, as it was done in Martinikenfeld, destroyed the bacteria of cholera and typhus, and it is especially to be observed that the generally more resistant typhus bacilli, despite the higher oxidability of the water, were destroyed just as readily as the less resisting cholera bacilli.

It is generally known that ozone first attacks the organic matter and then the bacteria, but we succeeded in limiting the effect on the organic matter and to completely destroy the bacteria. This is shown in the latest table of recent date, as of August 11, where the reduction of organic matter is inconsiderate, while the bacteriological result is very good.

Treatment of 10 Cubic Meters (+ 2700 Gallons) per Hour

Date	Serial Number of Experiments (9 each day)									Average	Number of Bacteria in Raw Water	Organic Matter in Solu- tion in Raw Water in Milligram Permanga- nate of Potassium	Per Cent. of Reduction in Organic Matter
	1	2	3	4	5	6	7	8	9				
Aug. 11	3	3	4	0	1	1	0	1	2	2	950	—	—
“ 12	4	0	4	3	1	0	1	2	3	2	1,000	.8	28%
“ 13	2	2	2	4	2	0	1	6	0	2	1,030	8.4	33%
Average										2			

We are able to produce water which is practically sterile. This does not mean, however, that in thousands of cubic meters per day not a single bacteria will be found. This is practically impossible. When, however, nine consecutive tests showed only two bacteria per centimeter, as the table showed, we are justified in calling this water sterile. We are able to leave it to the choice of others whether they desire practically sterile water with only 1 or 2 bacteria per cubic centimeter or a water low of bacteria ozonized, instead of filtered. The first, of course, is the most expensive. Drs. Ohlmuller and Prall further reached the following conclusions :

First.—By the treatment of water with ozone a remarkable destruction of bacteria is produced, and in this regard ozonization is in general superior to separation of bacteria by sand filtration.

Second.—The cholera and typhus bacilli are destroyed.

Third.—Viewed from a chemical point of view the water is affected only insofar that the oxidability is reduced and free oxygen increased, both of which mean an improvement of the water.

Fourth.—The ozone which is introduced in the water is of no importance from a technical or health affecting consideration, as it readily changes into oxygen.

Fifth.—The treatment of it improves the water by making it colorless.

Sixth.—The taste is not affected, etc.

Primary advantages are:

First.—That it is a clean mechanical arrangement securing a perfect regularity in operation without interruption from ice, conditions of weather, etc.

Second.—That in times of threatening danger by epidemics the quantity of ozone can be increased or the amount of water handled decreased.

Third.—The capacity of the plant can be readily increased as it simply involves a question of multiplying the units of apparatus.

Fourth.—It allows greater freedom in the choice of sources of supply, and, therefore, enters into the question of cost of transportation. These questions can, of course, not be exemplified in figures. The transportation of a water supply from long distances may involve millions. Again the cost of the installation depends on the quality of the water and size of the installation.

Mr. Vosmaer claimed the plant required a minimum of attendance and that it is practically self-operative. During the entire tests the only attention required was the keeping up of steam to workable pressure, and examining once a day the oil cups on the movable parts of the pumps, etc. In other words, the plant practically ran itself and the result obtained (see table) unquestionably sustained all that has been claimed for the Vosmaer system.

Remarks by Dr. van 't Hoff, bacteriologist for the Department of Water Supply of the City of Rotterdam, at meeting referred to:

I believe that the absence of complete sterilization in ozonized water, as discussed by Mr. Vosmaer, is attributable only to the presence of spore bacteria which are more resistant than the pathogenic. That being the case it is justifiable to say of this water that it is so barren of bacteria that it borders on sterility.

OZONIZATION OF DRINKING WATER:

What ozone is, and why it is claimed to be efficient and reliable as a positive remedy against the introduction and spread of pathogenic germs, such as typhoid fever, cholera, etc., through drinking water, will be better understood by reference to what has been said on the subject by well known scientists.

M. M. Pattison Muir, M. A., Fellow and Professor in Chemistry of Gonville and Caius College, Cambridge, England, in "The Story of the Wanderings of Atoms," says: "When oxygen is submitted to the action of the silent electric discharge a portion of the oxygen is changed into a substance which is a more energetic oxidizer than oxygen. This substance converts mercury, at the ordinary temperature, into black oxide of mercury, a reaction which is not accomplished by oxygen; when brought into contact with a solution of iodide of potassium it produces oxide of potassium, iodine, and oxygen, this also being a reaction which oxygen does not effect. When oxygen which has been submitted to the action of the silent electric discharge is cooled to about -180° C. (-292° F.) a blue liquid is formed; if this is allowed to evaporate oxygen passes off as a gas, and the modification of oxygen called ozone remains, presenting the appearance of a very dark blue liquid, and boiling at -106° C. (-214° F.). Liquid oxygen boils at about -181° C.

(-294° F.). Ozone is completely changed into oxygen by heating to low redness; the weight of the oxygen obtained is equal to the weight of the ozone used; the volume of the oxygen, however, is one and one-half times as great as the volume of the ozone. Ozone is one and one-half times heavier than oxygen, bulk for bulk; and, as a contraction of volume attends the formation of ozone from oxygen, ozone may be called condensed oxygen.

WHAT OZONE DOES:

It purifies air and when introduced into smoky rooms all smell disappears. It can be used with advantage for the purpose of purifying air in public buildings, theatres, club rooms, and in fact wherever crowds congregate. It may also enter into therapeutic use for curing first stages of consumption, and in many ways in manufacturing industries, for instance: the treatment of *linum usitatissimum* before it can be combed into flax can be greatly simplified and cheapened and the quality of the flax improved by the use of ozone, since it takes the glue from the raw flax and at the same time imparts an improved color to it; but its great field lies in the direction of purifying drinking water.

The following is a translation of the article by Drs. Ohlmuller and Prall, referred to by Mr. Vosmaer in his address before the Society of Hydraulic Engineers of Holland, convened at 's-Gravenhage on September 12 and 13, 1902:

The Treatment of Drinking Water with Ozone By Dr. Ohlmuller and Dr. Fr. Prall

When in the year 1891 Froehlich and his coöperators had shown the way of obtaining ozone in any quantity and degree of concentration desired from the oxygen of the

atmospheric air, the Imperial Board of Health determined to demonstrate the action of this substance upon bacteria. These inquiries have confirmed previous observations bearing on this question, and have proved especially, "*that ozone has a most powerful destructive influence on bacteria present in water, if the water is not too strongly contaminated with dead organic substances; the result is the same when the quantity of lifeless organic substance is oxidised to a certain degree.*" On the strength of this result it was not too bold to hope that after the production and application had been further developed it would be possible to make the application of ozone practically useful, especially with a view to the destruction of bacteria in drinking water.

The first attempts in this direction were made by Tyndall and his collaborator Schneller. These attempts induced Tyndall to build a large experimental station at Oudshoorn near Leyden. There water taken from the Old Rhine was treated with ozone. Van Ermengem tested the experiments and stated a satisfactory purification of the water. Tyndall then exhibited at the Paris hygiene exhibition in 1895 an apparatus with a purifying capacity of 2 cubic meters per hour. Since 1895 Abraham and Marmier have occupied themselves with the process, particularly with a view to the practical application of ozone. Otto and Gosselin and also Vosmaer have done good work in the perfection of the apparatus. Otto's apparatus acts well, as was shown by the tests applied by Loir and Fernbach.

In 1897 the process was exhibited at the Brussels Exposition and this led to the construction of an installation at Blankenberghe near Ostend, with a capacity of 2000 cubic meters per day; soon after, however, it was given up again, as it did not answer the expectations.

Another installation was built in 1898 by Abraham and Marmier, by order of the municipal corporation of Lille; its capacity was 35 cubic meters per hour; the water was ob-

tained from wells in Emmerin. A scientific committee appointed by the corporation submitted the installation to a thorough bacteriological and chemical test and found it to answer every requirement.

In 1900 the process, according to the Abraham-Marmier system, was on view at the Paris exhibition; the installation was described by Krull.

There is also an installation at Schiedam near Rotterdam; it has been built on Vosmaer's system and has a capacity of 20 cubic meters per hour.

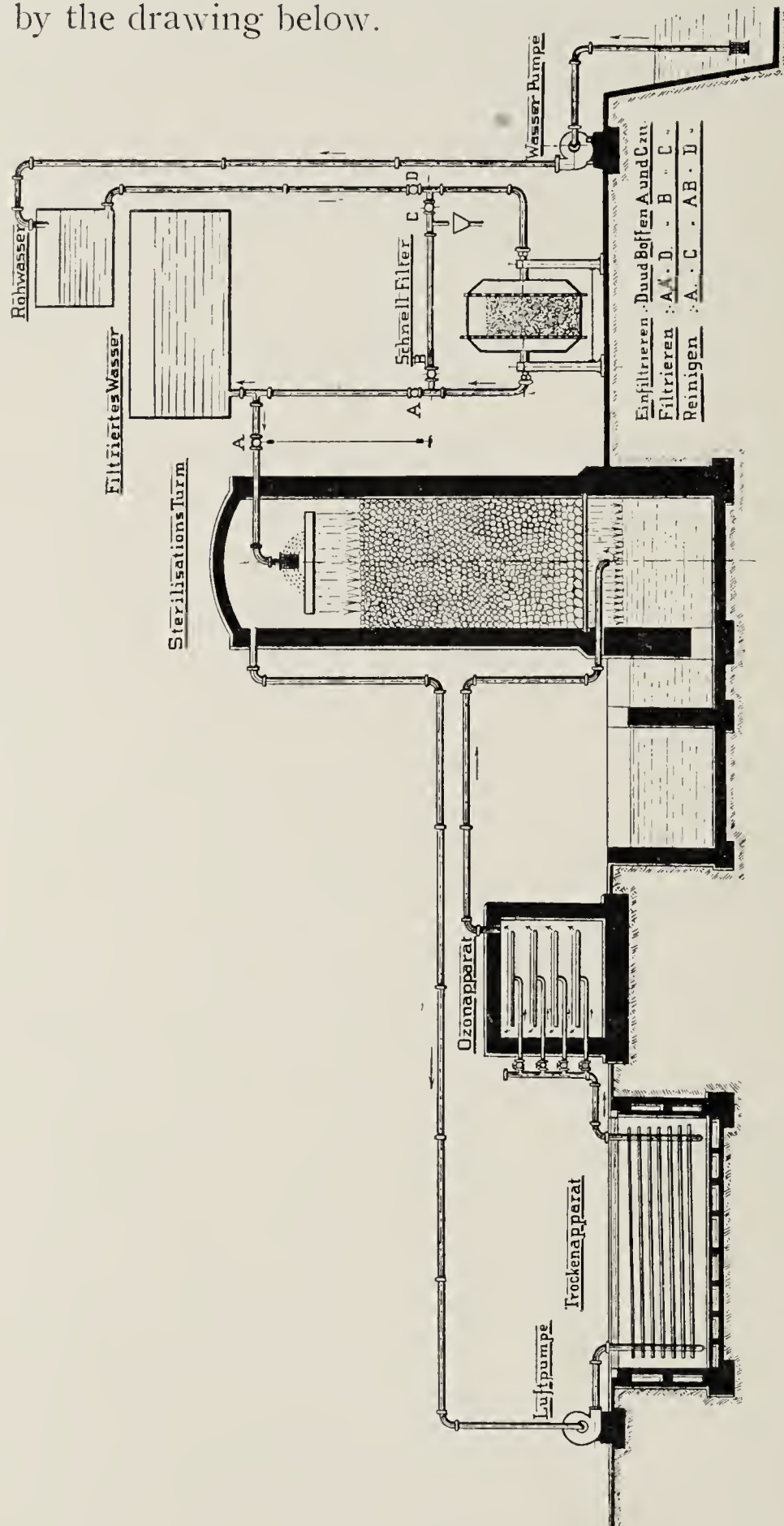
Messrs. Siemens & Halske in Berlin, who, as has been stated, first made ozone practically applicable, have exerted themselves, since the possibility of purifying drinking water by ozone was pointed out, to perfect the process by the construction of apparatus both for the production and the application of ozone. Weyl had an opportunity of testing the apparatus while still in construction.

Guided by the various results obtained they constructed a fairly large experimental station with a capacity of 10 cubic meters per hour, at Martinikenfeld, on the northeastern boundary of Berlin.

The object of this station was not only to give those interested in the process an opportunity to get acquainted with it, but also to demonstrate its practicability. The installation has been improved in various ways by hygienic and technical specialists and by members of scientific societies. The experiments made by the firm itself at the station, from a technical point of view as well as with regard to the condition of the water treated with ozone, have been dealt with by Erlwein in his treatise, "Trinkwasserreinigung durch Ozon nach dem System von Siemens & Halske (A.-G.) Berlin."

Owing to the great interest that had been taken in the subject of purification of drinking water by ozone, the Imperial Board of Health decided to make a series of experiments at the above station.

The arrangement of the Martinikenfeld station is clearly shown by the drawing below.



Ozone is prepared by pressing air by means of an air pump into the drying apparatus. It consists of a

refrigerator, the hose of which cools down the air and consequently reduces its moisture. The air dried in this way passes into the ozonizer, a box in which four pairs of plates made of glass and metal alternately have been arranged. Between these "blue glow discharges" takes place, produced by an alternating current of 10,000 to 15,000 volts tension. When the air passes through the spaces between the plates in which the discharges take place, its oxygen is partly transformed into ozone. The ozonized air then passes upward through the sterilizing tower.

In order to bring about the action of the ozonized air upon the water to be treated the following arrangement has been made:

By means of a pump the water (taken from the Spree) is raised to a basin for raw water; from here it runs by gravity through a Krönke filter (of which there are two), where the visible suspended matter is separated, and collects in a second basin. This filtered water is led from there to the sterilizing tower. The tower is built of brick, 5 meters high and one meter in diameter; the inside is cemented; it is closed all around with the exception of the inlets and outlets for ozonized air and water; the top is walled up; the bottom, which is provided on one side with a discharge pipe for the water, is placed in a water basin. This arrangement makes it impossible for the air entering at the bottom to escape; it is forced to go upwards through the tower and then, as far as it has not been used up, to escape at the top through a discharge pipe and to return to the ozonizing apparatus. The water, however, runs in the opposite direction; it enters at the top and runs out at the bottom. Consequently a countercurrent system is applied. In order to make the ozone act upon the water under the most favorable circumstances, the water is spread over the greatest surface possible. The ozonizing space proper is therefore filled with pebbles as big as eggs, which are arranged upon a frame. By means of a douche and a sieve the water is

divided into numerous jets, falls on the pebbles and drips down again, while all the time it is exposed to the action of ozone; after this it runs into the basin in which the tower stands, and on this basin running over, it is collected in a reservoir.

In order to test the efficiency of the installation a number of experiments were made. They were executed on the following plan: First the refrigerator was worked for one hour, so as to make it reach its maximum capacity for drying air; then the production of ozone began. In order that the sterilizing tower might always be in the same condition at the beginning of the experiment ozonized air and water from the Charlottenburg waterworks were made to run in counter-currents through the tower for half an hour or an hour. Then the real test began; the water to be treated was conducted through the tower; after half an hour samples of water were taken at regular intervals from the raw water basin, from the basin for filtered water and from the sterilization tower before the water had reached the "overrunning" basin; for this purpose a metal tube had been put in the wall of the tower, the mouth of which tube was sterilized before the beginning of the test by means of a flame. The samples for the bacteriological tests were taken with the usual precautions and then dealt with at once with a view to the determination of the number of bacteria. Of the raw and the filtered water 0.2 cubic centimeter or corresponding dilutions with sterile water, of the ozonized water 0.1 cubic centimeter was used for the culture. Plates with ordinary gelatine were prepared, in order to obtain results that could be compared with those arrived at elsewhere, and also plates with a culture substance consisting of gelatine, Agar & Heyden's culture substance, as it had been proved that in the latter the bacteria occurring in water developed in greater numbers. These numbers are therefore nearer to the truth. The plates obtained from non-ozonized water were, in accordance with Neisser's method, "counted" after two days; those

prepared with ozonized water after five days. All the plates were kept in a culture case at 22° . Moreover the raw, the filtered and the ozonized samples were submitted to a chemical examination; its oxidability, the quantity of ammonia, nitrous and nitric acids were determined, and in the middle of each test the quantity of residue at 116° was fixed. Finally the appearance of the water as to color and clearness and its taste were noted.

The production of ozone during these experiments was managed in such a way that a concentration of about 3 to 5 grams per cubic meter of air was obtained; during each experiment the quantity of ozone produced was only subject to insignificant, inevitable fluctuations. The percentage of ozone was during the experiment determined every half hour before and behind the sterilizing tower. As a rule 30 cubic meters of air went through the testing apparatus; in two tests 40 centimeters were employed with the same ozone concentration, in order to determine the result of this increase.

The quantity of water treated with ozone varied from 5 to 10 cubic meters per hour. Spree water and a mixture of such water and water from the Charlottenburg water-works in various proportions were employed to vary the oxidability and the number of bacteria within certain limits, as former experiments had shown that just these properties of the water are decisive for the action of ozone. A glance at the condition of Spree and of mixed water shows the minimum and the maximum values determined by the examination of these two:

Source of Water	Left after Evaporation	Oxidability in Milligram of Oxygen	Ammonia	Nitrous Acid	Nitric Acid	Number of Bacteria	
						Ordinary Gelatine	Gelatine, Agar and Heyden Food
I. Spree Water	172.4—233.6	7.52—10.88	0.2—0.3	0	0-Spur	35,700—185,800	48,000—412,400
II. Spree Water after Filtrat'n	181.4—204.2	6.16—7.12	0.0—0.24	0	0-Spur	5,700—26,950	8,900—69,300
III. Mixed Water	232.8—330.0	4.24—6.16	0.0—0.24	0	0	35,700—48,000	70,400—86,800

Water from the Charlottenburg waterworks—being subterraneous water—is richer in dissolved substances and power in organic matter than Spree water; consequently a greater proportion of the same in a mixture causes an increase of residue and a decrease of oxidability. By filtration through the Krönke filter the number of bacteria decreased. The water indicated Sub. II and III passed through the sterilizing tower; consequently ozone acted on water of such a nature that per cubic centimeter 5700-48,000 bacteria developed in ordinary gelatine, and 8900-86,800 in other culture substances. The latter numbers must be looked upon as the correct ones, the former having been adduced only to render comparison with other results possible.

For the sake of comparison with the above two kinds of water the composition of water from the old Rhine near Oudshoorn and that of the well water at Emmerin, both of which were also submitted to the ozone treatment, may be stated here:

Source of Water	Left After Evaporation	Oxidability in Milligram of Oxygen	Ammonia	Nitrous Acid	Nitric Acid	Number of Bacteria
Old Rhine, Unfiltered . . .	222	6.0	0.1	0	0.6	10,802
“ “ Filtered . . .	284	2.5	0.3	0	1.4	385
Spring Water	—	0.8	0.0	0.5	20.0	988—2,200

The water from the old Rhine, as subjected to the ozone process (filtered) possessed a lower oxidability and a smaller number of bacteria than Spree or mixed water; the oxidability of Emmerin well water was still less, while the number of bacteria was greater, though it did not come up to the number found in the two kinds of water treated here.

In the Martinikenfeld experimenting station water of a more unfavorable condition was purposely subjected to the ozone treatment, in order to determine the efficacy of the system.

Results of the Bacteriological Examination

In order to render it possible to state to what extent water bacteria are killed by ozone, the capacity of the ozone apparatus and the quantity of water treated must be known. Besides the number of bacteria in the filtered water passed through the apparatus, its oxidation coefficient *before* and *after* the treatment are also important. The results in this respect are stated in the table below; each number of bacteria is the average found in two plates.

Generally speaking the bacteria-destroying power of ozone was very considerable; in the case of bacteria cultivated in gelatine out of 5700 to 48,000 only 1 to 28 remained alive; in the case of those cultivated in other substances out of 8900 to 86,800 only 1 to 32. If the causes of less efficacious action are to be ascertained, they are, as was to be expected, to be found in the inferior condition of the water employed. In the case of unmixed (filtered) Spree water (experiments 1 and 2) the number of surviving bacteria was greater than in the case of mixed water. The quantity of water treated proved to be immaterial in this respect; the results were equally favorable whether 5, 7.5 or 10 cubic meters were used. Experiment 8 forms an exception; this will be referred to later on.

On the other hand, the conclusion suggests itself that the final result is determined by the quantity of ozone acting upon 1 liter of water and the amount of oxidizable substances (especially of dead organic matter and the number of bacteria). In experiment 3, 24.0-26.3 milligrams of ozone were employed; the oxidability was comparatively high,—5.84-6.16 out of the 14,300-17,400 bacteria 8-12 survived. On the other hand, in the case of experiment 10 only 12.1-13.5 milligrams of ozone (about half the quantity)

Number of Test	Day of Test	Hour of Test Taken	Kind of Water	Milligram of Water	Milligram of Air	Milligram of Ozone per Liter of Air		Milligram of Ozone per Liter of Water		Milligram of Oxygen		Reduction in Organic Matter	Bacteria per Cubic Centi- meter			
						Before	After	Applied	Used Up	Before Ozonization	After Ozonization		Ordinary Gelatine		Gelatine Agar and Heyden	
													Before Ozonization	After Ozonization	Before Ozonization	After Ozonization
1	27. III.	11 1 3	Spree Water	5,100 5,040 4,980	30,100 31,100 31,000	2.91 3.49 3.72	2.24 3.07 3.04	17.2 21.5 23.2	3.55 3.63 3.66	7.12 6.16 6.40	4.56 4.64 4.96	2.56 1.52 1.44	43,900 48,000 40,800	22 24 28	85,700 83,700 86,800	20 24 28
2	30. III.	11 1 3	Spree Water	7,560 7,200 7,500	30,300 31,000 29,600	4.13 4.42 4.44	3.09 3.43 3.37	16.5 19.0 17.5	3.80 3.86 3.84	6.96 7.04 7.04	5.44 5.44 5.44	1.52 1.60 1.60	36,700 36,700 35,700	27 26 26	70,400 83,700 84,700	23 25 22
3	2 IV.	11 1 3	2 Spree 1 Main Water	5,100 5,160 5,000	30,000 30,100 30,700	4.44 4.50 3.91	3.79 3.84 3.30	26.1 26.3 24.0	3.16 3.20 3.14	5.84 6.00 6.16	4.16 4.40 4.56	1.68 1.60 1.60	16,300 14,300 17,400	8 8 12	33,200 34,700 35,700	5 10 11
4	10. IV.	11 ³⁰ 1 3	1 Spree 4 Main Water	4,740 4,860 5,020	30,100 30,100 30,100	4.07 3.80 3.85	3.60 3.29 3.32	25.8 23.5 23.0	2.30 2.55 2.63	4.72 4.48 4.64	3.76 3.76 3.84	0.96 0.72 0.80	6,200 5,700 6,800	5 3 4	15,500 14,900 14,700	3 2 7
5	15. IV.	1 3 5	1 Spree 2 Main Water	5,300 5,220 5,490	30,700 31,100 30,100	3.48 3.50 3.66	2.82 2.88 3.02	20.2 20.9 20.0	3.30 3.20 2.99	5.20 5.04 4.96	4.24 4.24 4.00	0.96 0.80 0.96	8,700 6,900 5,800	3 1 4	13,500 9,900 8,900	3 3 1
6	18. IV.	11 1 3	1 Spree 2 Main Water	5,280 5,100 5,160	31,100 30,900 31,100	3.72 3.84 3.89	3.05 3.19 3.23	21.9 23.3 23.4	3.43 3.39 3.42	4.96 4.96 4.88	4.16 4.00 4.00	0.80 0.96 0.88	15,300 15,400 12,900	4 3 6	34,200 29,300 28,400	3 2 3
7	22. IV.	11 ³⁰ 1 3	1 Spree 2 Main Water	5,100 5,100 5,100	30,100 30,800 30,700	3.13 3.24 3.42	2.42 2.60 2.77	18.5 19.6 20.6	3.75 3.42 3.43	4.88 5.04 5.20	4.00 4.24 4.32	0.88 0.80 0.88	6,550 6,950 6,750	3 4 5	13,050 14,500 19,350	3 1 5
8	25. IV.	11 ³⁰ 1 3	1 Spree 1 Main Water	7,480 7,260 7,440	30,100 30,100 30,000	3.20 3.12 3.23	2.50 2.32 2.37	12.6 12.9 13.0	2.53 3.03 3.16	5.36 5.68 5.68	4.56 4.96 4.96	0.80 0.72 0.72	22,250 26,150 25,000	13 zer flossen	64,700 69,300 63,900	16 32 14
9	6. V.	11 1 3	1 Spree 4 Main Water	7,560 7,320 7,340	41,100 40,900 40,500	4.66 3.71 3.38	4.02 3.08 2.78	25.3 20.7 18.6	2.95 3.09 2.93	4.24 4.24 4.24	3.44 3.44 3.52	0.80 0.80 0.72	7,550 7,950 7,950	2 3 2	18,350 19,800 19,000	1 2 1
10	9. V.	12 1 ³⁰ 3	1 Spree 4 Main Water	7,500 7,560 7,440	31,100 30,000 30,100	3.17 3.04 3.35	2.41 2.27 2.56	13.1 12.1 13.5	2.87 3.79 2.88	4.32 4.32 4.40	3.52 3.52 3.60	0.80 0.80 0.80	16,950 17,700 26,950	3 3 5	32,350 35,000 62,900	3 3 6
11	15. V.	11 1 3	1 Spree 4 Main Water	7,200 7,200 7,320	30,700 30,700 31,100	3.50 3.71 3.78	2.77 2.94 3.03	14.9 15.8 16.1	2.78 2.92 2.98	4.40 4.48 4.48	3.52 3.60 3.68	0.88 0.88 0.80	6,750 9,000 10,000	5 2 2	16,650 19,700 21,550	11 5 2
12	24. VI	11 12 1	1 Spree 1 Main Water	10,200 9,800 10,100	40,800 40,000 40,000	5.45 5.18 4.66	4.25 4.03 3.41	21.8 21.1 18.5	4.43 4.28 4.61	5.76 5.76 5.76	4.80 4.80 4.80	0.96 0.96 0.96	16,850 17,350 19,400	1) 3 7	32,150 50,000 42,350	1) 7 11
13	27. VI.	11 12 1	1 Spree 1 Main Water	9,800 10,400 10,200	30,000 30,000 31,000	5.96 5.57 5.57	4.37 3.98 4.03	18.1 16.1 16.9	4.23 4.20 4.28	6.08 6.00 6.00	4.88 4.88 4.88	1.20 1.12 1.12	10,000 10,200 8,900	6 7 6	22,250 25,300 27,550	9 9 11

was used; the oxidability, however, was lower, 4.32-4.40 and consequently in spite of the greater number of bacteria (16,950-26,950) only 3-5 survived. That in the case of experiment 3 so much ozone was used up by the dead organic matter, is proved by the difference between the oxidation coefficients before and after the ozone treatment; in this case it amounted to from 1.60 to 1.68, in experiment 10, on the other hand, only 0.80 milligrams.

The unfavorable result of experiment 8 is to be accounted for in the same way; here high oxidability (5.36-5.68 milligrams) and a great number of bacteria (22,250-26,150) coincided with the small quantity of ozone employed (12.6-13.0 milligrams).

That the result depends to a greater extent upon a low oxidation coefficient of the water than upon a great number of bacteria, was shown by previous experiments; when the oxidability was greater, the destruction of the bacteria became more difficult; in distilled water it took place very quickly. With these new experiments, too, the oxidation coefficient played, generally speaking, the same part. Still it must cause some surprise, that in some cases in which both the oxidability and the number of bacteria were low, the result did not answer the expectations. So, for instance, in the first samples of water in experiments 4 and 11, showing a consumption of oxygen of 4.72 respectively 4.40 milligrams, 5 bacteria survived each time out of 6200, respectively 6750. This number seems too high as contrasted with the result of experiments 6 and 11, when with an oxidability of 4.96 milligrams 15,300 bacteria were all destroyed with the exception of four. The quantity of ozone employed does not sufficiently account for this result.

		To 1 Liter of Air, Milligram of Ozone	To 1 Liter of Water, Milligram of Ozone	Of this Used Up Milligram
Experiment	4	4.07	25.8	2.30
“	11	3.50	14.9	2.78
“	6	3.72	21.9	3.43

From this it appears probable that these results are to be ascribed to the presence of bacteria of greater resistance. The question arises if these cannot be destroyed by increasing the concentration of the ozone. This is not the case; the above table concerning these three experiments shows that the consumption is not proportionate to the concentration; when the latter was highest (experiment 4) the consumption was smallest. The condition of the water, especially its oxidation coefficient and the number of bacteria and the kinds of these, is decisive for the result. A concentration of about 3.0-5.5 grams ozone in 1 cubic meter of air, as applied in these experiments, is sufficient. Still though in the case of the experiments in the Lille installation concentrations of 5.8-9.5 grams were applied, some germs of *bacillus subtilis* survived. Abraham does not think it advisable to go below a concentration of 4-5 grams.

When the bacteriological results of these experiments are compared with those obtained at Lille and Oudshoorn, the Martinikenfeld experimenting station has shown a satisfactory capacity. That in the former fewer or no bacteria survived, is to be ascribed to the condition of the water with which the experiments were made there. In Oudshoorn the filtered water from the Old Rhine contained 385 bacteria, the oxygen consumption being 2.5 milligrams; the well water of Emmerin near Lille contained 988-2200 bacteria; the oxidability being as low as 0.8 milligrams. In the water used for the inquiries here the number of bacteria varied between 5700 and 48,000, the oxidability being from 4.24 to 7.12 milligrams. In Oudshoorn perfect sterility was obtained, in Lille specimens of *bacillus subtilis* occasionally escaped; in these experiments 1 to 28 bacteria survived (on gelatine plates). In spite of the water being of inferior condition, it has often been observed that one of the two plates that supplied the above averages was sterile; this was the case with experiments 5, 7, 9 and 10.

Even though the bacteria destroying action of ozone

upon water is so considerable, still it is not to be avoided that some bacteria survive. This is owing to the greater resistance of certain bacteria; still the oxidation coefficient of the water is to be taken into account as well. It would be unreasonable to expect a water ozonizing installation *always* to supply water perfectly free from bacteria; this has not been obtained by any of the central water purifying methods now known. Nor is this necessary from a hygienic point of view; in the case of sand filtration, the method generally applied for the purifying of surface water, a decrease of the number of bacteria to 100 per cubic centimeter is considered sufficient. This object is reached to perfection with the ozone system, for it has been proved to be possible to reduce the number of 83,700-86,800 bacteria in Spree water roughly filtered through a Kroehnke filter in order to remove suspended matter to 20-28. It may be emphasized that the water was taken from the Spree below Berlin, after it had been exposed to many forms of contamination on its course through this city. When the ozone method is employed—as well as in the case of sand filtration—the most favorable conditions of the “raw” water will of course be preferred, and even on esthetical grounds the pumping station will not be established *below* a city; here it was done only by way of experiment.

By sand filtration the reduction of the number of bacteria is brought about mechanically; the ozone method does this chemically. Experience shows that sand filtration is so efficacious that if the filter is properly attended to the danger of infection by purified water is reduced to an allowable minimum. Still C. Fraenkel and C. Piefke have proved that under certain circumstances pathogenic micro-organisms pass through the filter; all the same many years' experience has shown that the use of water purified by sand filtration cannot be objected to.

As regards the ozone methods, the behavior of pathogenic micro-organisms has still to be ascertained, as it has been proved that bacteria with greater resisting capacity

were not attacked under certain circumstances. Especially the cholera and the typhus bacillus are to be considered here as being causes of infection. In order to make preliminary researches experiments were made in the laboratory with a small apparatus of the same construction as those in the station. In order to render the capacity of this laboratory apparatus comparable with those at Martinikenfeld, the supply of air and water was arranged in such a way as to bring about the same reduction in the number of bacteria in a mixture of Spree and waterworks water in equal proportions as was ascertained in the experimenting station. With this apparatus water was treated containing cholera and typhus bacteria (for the sake of comparison coli bacteria were also employed), obtained from 1-3 days' old agar cultures in sterilized Spree water at 30° or in a mixture of this water with equal parts of waterworks water; mixtures of water were employed to obtain various oxidation coefficients. The bacteria in question were introduced in such great quantities that numbers of germs were obtained as never occur in ordinary impure water; this was done partly to force the experiment, partly with regard to the fact that the action of ozone is influenced by the number of germs and the oxidability. Before and after the ozonization two gelatine plates were prepared with the water each time; the former were counted after two, the latter after ten days. The results were as follows:

a. Bac. Cholera in Spree Water, 16,350 per Cubic Centimeter. Incubation 1 day at 30°C.

Milligram of Ozone per Liter of Air	Oxydisability Milligram of Oxygen Per Liter		Reduction in Or- ganic Matter	Number of Bac- teria after Ozo- nization
	Before Ozonization	After Ozonization		
5.49	7.92	6.88	1.04	0
4.53	7.92	6.96	0.96	0
3.45	7.92	7.04	0.88	0
2.88	7.92	7.12	0.80	0

b. Bac. Cholera in Mixture of Spree and Main Water, 1 : 1 17,850 per Cubic Centimeter. Incubation 1 day at 30°C.

5.19	5.72	5.00	0.72	0
4.41	5.72	4.88	0.84	0
3.39	5.72	5.04	0.68	0
2.61	5.72	5.04	0.68	0

c. Bac. Typhus in Spree Water, 39,050 per Cubic Centimeter. Incubation 1 day at 30°C.

4.89	8.40	7.36	1.04	0
4.20	8.40	7.52	0.88	0
3.54	8.40	7.60	0.88	0
2.73	8.40	7.76	0.64	0

d. Bac. Typhus in Mixture of Spree and Main Water 1 : 1 31,400 per Cubic Centimeter. Incubation 3 days at 30°C.

5.31	5.60	4.64	0.96	0
4.56	5.60	4.72	0.88	0
3.24	5.60	4.68	0.92	0
2.49	5.60	4.76	0.84	0

e. Bac. Coli in Spree Water, 30,600 per Cubic Centimeter.

5.28	7.84	6.88	0.96	0
4.56	7.84	6.96	0.88	0
3.42	7.84	6.88	0.96	0
2.49	7.84	6.86	0.88	0

f. Bac. Coli in Mixture of Spree and Main Water, 1 : 1 36,000 per Cubic Centimeter.

5.31	5.84	5.04	0.80	0
4.44	5.84	5.04	0.80	0
3.30	5.84	5.20	0.64	0
2.64	5.84	5.24	0.60	0

Against these experiments it may be objected that they do not irrefutably prove the destruction of the bacteria, as there is a possibility of their having their power of developing in gelatine through the action of ozone. Therefore two further experiments were made under equal circumstances as regards the passage of air and water, while cholera bacteria were added to the non-sterilized water, and their presence was ascertained by the "Enriching" method (by a peptone and salt solution). The results were as follows:

Kind of Water	Milligram of Ozone per Liter of Air	Milligram of Oxygen Used to Oxidize 1 Liter of Water		Reduction in Or- ganic Matter	Total Number of Bacte- ria in One Cubic Cen- timeter	
		Before Ozonization	After Ozonization		Before Ozonization	After Ozonization
Spree and Main Water	3.48	6.16	5.28	0.88	45,170	6
I in I	3.54	6.22	5.28	0.96	43,890	5

These two experiments with the small apparatus show the same result as was observed in the great experimenting installation at Martinikenfeld, viz: a decrease of oxidability to the number of germs in the same degree. The capacity of the small apparatus was consequently properly adjusted in comparison with the large installation.

"During the experiments six samples of 90 cubic centimeters were taken from the ozonized water, and two from the water not yet treated, and then submitted to the enriching method; in the latter cholera bacteria could be detected, in the ozonized water they had been destroyed."

After these two preliminary experiments two definitive ones were made in the large ozonizing apparatus, in which cholera or typhus bacteria were added to a measured quantity of water. Measures were taken to prevent the spreading of

the pathogenic bacteria. The passage of the ozonized water from the "overrunning" basin to the reservoir was walled up. The connecting tube between the Krönke filter and the basin for filtered water was removed, and the joint screwed up; under the cock A' a basin containing a sublimate solution was placed to disinfect any water that might drip off. The cock, however, proved to be so perfectly tight, that no water dripped off. The quantity of water to be infected was made so great that it could be contained in the "overrunning" basin. This made it possible to sterilize all the water employed; this was done by making it boil with steam. For this purpose a pipe was laid from a boiler carrying a steam pressure of 10 atmospheres to the "overrunning" basin and the basin for filtered water.

The arrangement of both experiments was as follows. First the basin for filtered water was filled with 1 cubic meter of water (a mixture of Spree water and water from the waterworks). For the cholera experiment it was used without any further preparation; for the typhus experiment it was heated to the boiling point by means of steam, in order to facilitate any difficult typhus diagnosis through the destruction of the water bacteria. As appeared later on, the sterilization of the water was not perfect; perhaps the heat was not applied for a sufficient length of time; certain it is that during the cooling, which was brought about by leaving the water during the night and letting a piece of ice float in it, germs got into it.

To the water in its natural condition cholera bacteria, to the boiled water typhus bacilli were added. Both cultures (agar) were 1 day old and had grown at 37°. Cholera bacteria were added in such a quantity that according to estimate there were 2000 in every cubic centimeter; as to the number of typhus bacilli the determination of the number of germs on the gelatine plates fixes it approximately. In order that

the pathogenic bacteria might be evenly distributed, the water was stirred vigorously.

In the meantime the ozone apparatus was put in motion to make the refrigerator reach its maximum drying capacity and to obtain the desirable concentration for ozone. When the apparatus was in full action, the infected water was passed through the sterilizing tower. During the process samples of water were taken to determine the oxidability and the number of germs, and others for the direction of pathogenic bacteria, viz: two samples before treatment, and ten of the ozonized water, which in the case of cholera amounted to 180 cubic centimeters, in the case of typhus to 100 cubic centimeters.

When the experiment was finished, the basin for filtered water was filled with 1.75 cubic meters of water. Then steam from the boiler was conducted into this basin and into the "overrunning" basin; in the latter the steam tube was next pushed into the sterilizing tower, to make the water in it boil; then the water outside in the "overrunning" basin was treated in the same way. When the boiling heat had been kept up in both basins for half an hour, the water in the basin for filtered water, while kept at the same temperature, was allowed to run into the "overrunning" basin, and in order to sterilize the connecting tube to the sterilizing tower the latter was rinsed with 10 liters of alcohol. In the "overrunning" basin the boiling heat was kept up for another one-quarter hour, and then the contents were allowed to run into a freshly dug sandhole $1\frac{1}{2}$ meters deep, after which the hole was filled up. There are no wells in the vicinity of the hole. In order to sterilize the inside of the tower, ozonized air was passed through for one hour. By such precautions spreading of the bacteria was entirely excluded. It may be stated that during these two experiments the production of ozone was conducted by the Engineer Friberg; the infected and the ozonized water was not touched by any one besides ourselves.

Of the results of the experiments we will first state those bearing upon the general inquiry :

	Quantity of Water per Hour in Cubic Meters	Quantity of Air per Hour in Cubic Meters	Quantity of Ozone Grams per Cubic Meter	Oxydisability of Water Expressed in Milligram of Oxygen Used Up per Liter of Water	Oxydisability of Water Expressed in Milligram of Oxygen Used Up per Liter of Water After Ozonization	Reduction in Oxydisability	Total Number of Bacteria per Cubic Centimeter Before Ozonization	Total No. of Bacteria per Cubic Centimeter After Ozonization
Number of Bacteria, Cholera :								
1 Part of Spree Water .	7	38	3.76	4.64	4.00	0.64	38,330	8
2 Parts of Main Water .	—	—	—	—	—	—	—	—
Number of Bacteria, Typhus :								
2 Parts of Spree Water .	7	38	3.79	9.36	8.16	1.20	16,590	9.2
1 Part of Main Water .	—	—	—	—	—	—	—	—

Both experiments proceeded quite regularly ; they had the same result as previous ones, viz : a decrease of oxidability and a considerable lessening of the number of germs in the water. It is specially remarkable that in the typhus experiment there was such a high oxidation coefficient as had never before been observed. This makes the experiment all the more important, as the number of germs, too, though smaller than that in the cholera experiment, cannot be called small.

The samples taken for the detection of pathogenic germs underwent a further treatment. Those obtained from the cholera experiment were, after the addition of pepton and salt, treated by the “enriching” method. Some of the “enriched” water was spread on agar plates. From these the colonies suspected to consist of cholera bacilli were removed by oculation for further treatment by gelatine plates, cholera red reaction being made use of. The original cholera pure culture with which the water had been infected served as a basis of comparison. The detection of cholera bacteria in the infected, non-ozonized water was possible in the case of both

samples through gelatine culture and nitrosoindol reaction. The ten samples of ozonized water were treated in the same way; the cholera red reaction, however, did not appear in any of the cultures that had been inoculated as being suspected of containing cholera bacteria. The detection of typhus bacilli was also introduced by an "enrichment" process, viz: by the addition of bouillon in equal quantities of the water to be examined, and by leaving the samples for 18 hours in a temperature of 37° ; after this some was spread out on agar plates. Out of the typhus-like cultures agar pure cultures were prepared, and these were compared with the original typhus culture which had served to infect the water, as well as with a pure culture of bacteria coli commune by the usual methods of typhus diagnostics. From the infected, non-ozonized water cultures were obtained, which in colored preparations, in suspended drops, by their growing on gelatine, agar and potatoes, by their behavior in sterile milk, grape-sugar solution, litmus and Maassen's non-albuminous culture fluid, and especially through R. Pfeiffer's immunity reaction proved to be typhus bacilli. On the other hand, the 26 pure cultures (suspected to be typhus bacilli) obtained from agar plates out of ozonized water, proved on the above methods being applied, not to be typhus bacilli.

"These two experiments, therefore, have proved that by the treatment of water with ozone in an installation like the one at Martinikensfeld the bacteria of cholera and typhus are destroyed. This result is confirmed particularly by the fact that generally speaking typhus bacilli with a greater power of resistance, in spite of the high oxidability of the water, were destroyed as surely as the less resistant cholera bacteria."

The Result of the Chemical and the Physical Examination

It must be required of any method that is to make any kind of water, subterraneous or surface water, fit for use, that the injurious ingredients of the water are removed or reduced to an allowable minimum, that the dissolved substances which

we consider an advantage in good drinking water, are not appreciably changed, and that no foreign substances which have an injurious influence upon water used in food or as a beverage, are added to the same.

In what manner the ingredients that are not dissolved are influenced by the ozone process, has already been shown. The visible suspended matter is removed by the Krönke filter, the bacteria are with the exception of a few, destroyed by the action of ozone. It is true, it has not been proved that the cell substance of the dead bacteria is completely destroyed by oxidation; still this amount of organic matter even in water that is very rich in bacteria, is of no importance whatever on account of its small quantity. As to the influence on dissolved substances the chemical analysis of the water gives the desired information; the values obtained varied between the following limits: 1 liter of water contained milligrams:

	Solid Matter	Organic Matter (Oxygen)	Ammonia	Nitrous Acid	Nitric Acid
Filtered Spree					
Water .	181.4-204.2	6.16-7.12	0.2-0.3	0	0 to trace
Mixed Water	232.8-330.0	4.24-6.16	Trace to 0.24	0	0 to trace
Ozoniz'd W't'r	181.2-330.0	3.44-5.44	" " 0.24	0	0 to trace

The residue figures show that the weight of the dissolved, non-volatile ingredients of the water has not been altered by the action of ozone; they vary within the same limits in the ozonized water as in Spree and mixed water. On the other hand a considerable decrease of oxidable substances has taken place; this means an improvement of the water. Taking the great oxidizing power of ozone into consideration, it must cause surprise that the nitrogen compounds have been influenced so little; it might at least be expected that free ammonia would be oxidized into nitric acid. Special experiments throw light on this point; they were executed with the small laboratory apparatus; solutions of various concentrations in distilled water being used.

Froehlich had already shown on former occasions, that in air being ozonized small quantities of nitrous and nitric acid—depending on circumstances—are formed from the nitrogen. This is accounted for by the fact that on an electric spark passing through nitrogen and oxygen nitric acid is obtained. By preliminary experiments it was possible to ascertain that in the ozone apparatus a small percentage of the atmospherical nitrogen was changed into nitric acid; lower stages of oxidation, especially nitrous acid, did not come into play. The result obtained was as follows :

Time taken for Experiments in Seconds	Quantity of Air in Liters	Quantity of Ozone in Milligram per Liter	Total Quantity of Ozone Milligram	Total Quantity of Nitric Acid
455	20	3.00	60.0	7.28
540	20	3.96	79.2	8.78
490	20	8.4	168.0	16.80
230	10	10.44	104.4	12.19

In order to obtain a clear idea of the action of ozone upon the ammonia present in the water, the nitric acid given off by the air was extracted from the ozone by means of concentrated sodium lye. The formation of nitric acid in water was so insignificant in these experiments, that a quantitative determination was not worth while; only the shades of blue of diphenylamine-sulphuric acid could be fixed. In the table below the presence of nitric acid is indicated as follows :

By o	no trace.
+	hardly a trace.
++	very slight trace.
+++	slight trace.
++++	a trace.

The result was as follows :

Free Ammonia									
Cubic Centimeters of Water per Minute	Liters of Air per minute	Milligram of Ozone per Liter of Air	Milligram of Ammonia per Liter of Water						
			5	10	20	30	40	50	100
40	2	2.5	0	0	0	0	+	+	
40	2	4.0	0	0	+	+	+	+	
40	2	5.5	0	+	+	+	+	+	
40	2	10.5	+	+	+	+	+	+	+

Carbonate of Ammonium									
40	2	2.5	0	0	0	0	0	0	0
40	2	2.0	0	0	0	0	0	0	0
40	2	5.5	0	0	0	0	0	0	0
40	2	10.0	0	0	0	0	0	0	0

Chloride of Ammonium									
40	2	2.5	0	0	0	0	0	0	0
40	2	4.0	0	0	0	0	0	0	0
40	2	5.5	0	0	0	0	0	0	0
40	2	10.0	0	0	0	0	0	0	0

Free ammonia, therefore was oxidized only when strongly concentrated or when the percentage of ozone was high, and even then only in a slight measure ; in a compound form as a carbonate or as a chloride, ammonia was not influenced at all.

Nitric acid, both when free and in a compound, behaved differently. The experiments yielded the following results :

As Free Nitrous Acid Per Cent. Oxidized to Nitric Acid

Cubic Centimeter of Water per Minute	Liters of Air per Minute	Milligram of Ozone per Liter of Air	Milligram of Nitrous Acid per Liter of Water			
			5	10	20	50
50	3	2.30	100	60	45	20
50	3	3.50	100	75	50	30
50	3	4.30	100	80	55	35
50	3	6.00	100	100	75	45

Combined to Sodium Per Cent. Oxidized to Nitric Acid

50	3	2.80	100	95	85	70
50	3	3.50	100	100	94	80
50	3	4.30	100	100	100	87
50	3	6.00	100	100	100	92

Here as opposed to the result obtained in the case of ammonia, it is to be observed, that the oxidation is greater when the dilution is stronger. Further it is particularly striking, that of the nitric acid in compound from a greater quantity is oxidized than of free nitric acid; this fact is accounted for by the alkaline reaction of the nitrous sodium. For it has been proved that the action of ozone upon oxidable substances is more powerful in the case of alkaline, than in the case of acid and of neutral reaction of water,

Kind of Water	Reaction of Water as it is or altered by Addition of 10 CC. of Normal Sulphuric Acid Resp. Caustic Soda to One Liter	Per Minute Passed		Milligram of Ozone per Liter of Air	Milligram of Oxygen Required to Oxidize One Liter of Water		Reduction in Organic Matter
		Liters of Air	Cubic Centimeter of Water		Before Ozonization	After Ozonization	
Spree Water	Neutral	3	50	4.3	7.84	6.64	1.20
	Acid	3	50	4.3	7.84	6.48	1.36
	Alkaline	3	50	4.3	7.84	5.36	2.48
Spree and Main Water 1 in 1	Neutral	3	50	3.0	6.24	5.20	1.04
	Acid	3	50	3.0	6.24	5.20	1.04
	Alkaline	3	50	3.0	6.24	4.80	1.44

The reader may be reminded of the well-known fact that the presence of nitrogen compounds in water is ascertained only in so far as from this the nature of the contamination can be inferred; from a physiological point of view they are, in the quantities in which they are usually found in drinking water, of no importance. Hence the small changes which they experience through the action of ozone are of no moment.

In reality the chemical composition of water is only in so far influenced by the ozone treatment, that ozone is dissolved, besides decreasing the oxidability. The ozone, however, is reduced to ordinary oxygen, and this happens the more quickly, the proportion as the oxidability of the water before treatment was higher; as a rule no ozone was to be detected after 15-20 seconds. Therefore any injurious action of ozone upon the piping is excluded. On the other hand the increase of oxygen in the water as well as the decrease of oxidability means an improvement.

From a physical point of view, it was observed that the yellowish color of river water entirely disappeared; the ozonized water was always colorless and clear. A foreign taste or smell was never observed in it.

In order to have a guarantee, that the ozone installation always acts rightly in every part, the engineer Friberg has invented ingenious, automatic apparatus. As soon as disturbances occur in the supply of air or in the production of ozone, a bell signal is heard, and the dropping of a valve on a signal board indicates the cause of the disturbance; at the same time the current of water into the sterilizing tower is automatically turned off. In this way it is impossible for water that has not been subject to the action of ozone to leave the apparatus.

The results of our experiments may be summarized as follows:

(1) By treating water with ozone a considerable destruction of bacteria is brought about; in this respect the

ozone method is, generally speaking, superior to the removal of bacteria by central sand filtering;

(2) Cholera and typhus bacteria present in water are destroyed by the ozone method;

(3) Chemically the water is influenced by the method only in so far as a decrease of oxidability and an increase of free oxygen takes place; both mean an improvement of the water;

(4) The ozone that is dissolved in the water during the process, is technically and hygienically of no consequence, as it very quickly changes into oxygen;

(5) The method improves the water by the destruction of coloring matters, and

(6) Owing to this the water becomes free from any foreign taste and smell.

Consequently the ozone method can in certain cases compete with other known and tried methods of central drinking water purification. As in the case of all other methods the condition of the raw water will have to be taken into account, and especially the degree of oxidability will have to be paid due attention to when ozone is employed.

On page 5 of “Public Water Supplies,” by John W. Hill, Consulting Engineer, Philadelphia, appears the following: “The management of the filters and maintenance of the quality of water supplied to the chief cities of Holland are as carefully conducted in the interests of the public health as are the boilers and pumping engines operated in the interest of the public purse. By the combined efforts of the engineers, chemists, and bacteriologists connected with the waterworks of Holland, the water is pumped with the greatest economy of fuel and is con-

sumed by the people with the least loss of life from water-carried diseases.”

On page 8 of the same edition, referring to the Rotterdam filter plant, he says, “Bacteriological tests are made every day.”

On page 139 Mr. Hill says: “The water of Rotterdam and Berlin is filtered, the first from the River Maas, and the second from the Rivers Spree and Havel, both of which have received sewage and surface drainage from urban and rural territory before the water reaches the intakes of these works.”

On page 207, under the head of Typhoid Fever Statistics, “the death rate per hundred thousand of Rotterdam, Holland, is among the very lowest.”

During the months of February and March, and up to the date when the writer left Holland, April 12, the following notice appeared daily in the *Nieuwe Rotterdamsche Courant*:

KENNISGEVING.

BURGEMEESTER en WETHOUDERS van Rotterdam,

Overwegende, dat uit de resultaten der geregelde controle door de directie der gemeentelijke drinkwaterleiding op het ten gebruike af te leveren water geoeffend, het vermoeden is voortgevloeid, dat bedoeld water niet als volkomen vrij van typhus-kiemen is te beschouwen en dat als gevolg daarvan, reeds dadelijk in overleg met de gezondheidscommissie, de burgerij bij openbare kennisgeving tegen het gebruik van ongekookt water en ongekookte melk is gewaarschuwd;

Overwegende dat een nader onderzoek, sedert door professor dr. Eykman te Utrecht ingesteld, dit vermoeden heeft bevestigd;

Gehoord de gezondheidscommissie en den betrokken inspecteur der volksgezondheid;

besluiten:

te verklaren dat, onder de tegenwoordige omstandigheid, het gebruik van ongekookte leidingwater de ingezetenen aangevaar blootstelt, en er opnieuw met allen ernst op aan te dringen dat, terwijl alles wordt in het werk gesteld om de oorzaken der besmetting weg te nemen, voorshands ook dit drinkwater niet dan gekookt worde gebruikt.

Burgemeester en Wethouders voornoemd,

De Secretaris,

De Burgemeester,

HEYNSIUS.

s'JACOB.

which, translated into English, reads as follows:

NOTICE.

The Mayor and Councils of Rotterdam considering that, from the tests results obtained by the regular supervision of the city's water supply, it is suspected that the water is not free of typhoid germs, and in consequence thereof the Board of Health by public announcements promptly warns the citizens against the use of unboiled water and unboiled milk.

And considering a later investigation made by Prof. Dr. Eykman of Utrecht has confirmed this suspicion, after consultation with the Board of Health and the Inspector.

Resolved, To give notice that under present conditions the use of unboiled water exposes the citizens to danger, and to strongly insist to not use this drinking water unless it be boiled first, while everything is being done to eliminate the cause of the pollution.

THE MAYOR AND COUNCILS,

HEYNSIUS,

s, JACOB,

Secretary.

Mayor.

In addition to this the city was liberally placarded with large printed notices of a similar nature, warning the citizens against the use of water or milk unless first boiled, and recommending the washing of hands in previously boiled water before taking food.

The writer visited the Waterworks at Rotterdam, Holland, on Thursday, February 11, and was courteously afforded by Dr. Van 't Hoff an opportunity to inspect the filter system, and in fact every part of the plant, and in an interview with Dr. Van 't Hoff, the latter admitted that his confidence in the reliability of sand filtration was shaken, and this is in accord with what Mr. Hill says on page 131 of his same work:

“Some writers in their enthusiasm have declared that sand filters properly constructed and operated will furnish pure water. This is a mistake. No filter operated upon a practical basis has ever furnished pure water; but the so-called purified water is so much superior to the unfiltered water that it will meet the practical requirements of cities and communities to-day and **‘when the time is reached that the people demand absolutely pure water, the methods for furnishing it will doubtless be forthcoming.’** For the present, and as a practical method of water purification, filtration may be regarded as entitled to full credit at the hands of city officials and waterworks managers.”

“Filtration, as the term is defined and generally understood, consists of an interception or straining out from a fluid such suspended matter as is larger in some dimensions than the pores of the filtering medium. The action is supposed to be purely mechanical, and the efficiency of a filter will be measured by the fineness or coarseness of the filtering material. The filtration of water, however, demonstrates that the fineness of the filtering material is not exactly a measure of the efficiency, and the finest or smallest grain of sand does not always give the best results.

"This fact, then, would naturally suggest that the straining action is only a part of the work accomplished by the filter; and in addition to the interception of certain suspended matters at the surface of the sand-bed, some other forces are at work to reduce the suspended matter, including the bacteria, in the water. One of these forces is now known to be the action of the bacteria on the organic matter. This is called the biologic action of the filter.

"The bulk of the suspended matter, including the bacteria in water, will be intercepted at the surface of the sand. Here the process of splitting up the organic matter into its nitrogenous and carbonaceous elements is continually going on; the carbons going off as carbon dioxides and other gases, and the nitrogenous matters being converted into nitrous and nitric acids, which in turn unite with the bases in the water, forming nitrites and nitrates, in themselves harmless products of bacterial action.

"This biological action of a filter is, after all, its most important function. The simple straining process of a bed of sand or of other filtering material, while competent to render turbid water clear, could have but little effect upon the bacteria, because many of these are so small in some dimensions as to grow through a sand-bed of almost any practicable fineness. The action of the organisms in the water on the organic matter results in the production of a thin semigelatinous film over and around the grains of sand in the upper layers of a bed, which in due time becomes so dense as to clog it, and requires a high head to force the desired amount of water through the sand; whereupon such sand-bed is temporarily taken out of service, the water drawn down some distance below the surface, and the upper fraction of an inch of the sand removed. With the new surface of sand exposed, the filter is ready for service again.

"When the water is drawn off a filter for renewal of the surface of the sand-bed, two important events occur. One consists of the paring off of a thin layer of the clogged sand

mentioned above; and the other of a complete or partial aëration of the sand-bed, by means of which the nitrifying bacteria in the bed are supplied with air (oxygen), without which, according to the authorities who have especially studied these organisms, the nitrifying bacteria would soon perish, and their functions in the reduction of nitrogenous organic matter to nitrous and nitric acids be lost.

“All sand filters are therefore intermittent filters. None work continuously. Each time the water is drawn below the surface of the sand-bed, there is a partial aëration of the sand; and when the water is drawn off entirely, during the operation of paring away the upper one-half ($\frac{1}{2}$) inch or so of dirty sand, the bed is rested, as it were, and complete aëration occurs.

“This upper dirty layer of sand, which contains inorganic matter intercepted from the water, and the products of vital activity of the water bacteria, is called the ‘Schmutzdecke’ by Mr. Piefke, who, the author believes, was the first to point out the manner in which the semigelatinous film was formed, and how it consisted of intercepted matter in suspension, and organic matter in process of destruction by bacterial agency.”

And further on, “The ‘Schmutzdecke,’ or film of intercepted suspended matter and products of bacterial action, is a delicate membrane lacking in consistency, and easily broken by too rapid changes of pressure (head) on the sand-bed; and when broken bad results are liable to follow. The author cannot do better than quote from Mr. Gill upon this feature of sand filtration:

“ ‘Since the bacteria are liable to be washed downwards by a stream of greater force than that which prevailed when they came into contact with the sand grains, it is of the utmost importance to avoid an increase of speed, especially a sudden increase. Mechanical arrangements must be adopted to prevent this, and it must be impossible that any filter in action can in any way effect the yield of the neighboring

filter. The chief cleansing action takes place in the mud deposit on the surface of the sand, and in the sand immediately at the surface. In this region the coating of deposit is soft, and with its dense population requires careful and tender treatment to avoid squeezing out the bacteria by undue pressure. It is obvious that as soon as an appreciable deposit has taken place on the sand surface, any increase of "head" must be chiefly caused by the layer of this deposit. If the sand beneath is not absolutely homogeneous, as it cannot be, any increase of pressure may cause a depression and a tearing of the mud-skin on the less dense parts of the surface of the sand. Through such a rupture the bacteria are at once washed by the increased local current which ensues into the sand beneath, and may be carried through the entire layer. Yet a gradual increase of pressure must of necessity take place, when the yield is to be constant, in order to overcome the increasing friction of the passage of the water through the filtering medium, in proportion as its interstices become gradually closed by the deposit. Nor is such increase, if gradual, injurious, provided certain limits be not exceeded."

The efficiency of the sand filter bed then is dependable upon its biological action in which the *Schmutzdecke* plays the most important part, yet it is this *Schmutzdecke* which interferes with the flow or capacity of the filter, and for this reason requires to be removed whenever the capacity has been reduced to a point beyond which the filter bed becomes practically useless.

In the *Deutsch Revue*, of May, 1903, edited by Richard Fleischer, an article by Dr. H. J. Van 't Hoff appears, entitled

WATER SUPPLY OF CITIES.

OZONE AND ITS APPLICATION TO THE PURIFYING OF DRINKING WATER.

from which I translate the following:

“Experts in matters of hygiene and business men agree that dune water and deep well water may be considered as ranking first in quality for drinking purposes, but it is not possible for every community to command either of these sources. In that case, there is nothing left to do but to make use of surface water, although this may contain more or less infected substances. The science of filtration has lately reached such a high point of perfection that we may be permitted to say that a thoroughly supervised waterwork can furnish the very best results, and that more epidemics have their source in ground water than in well controlled or supervised surface water; but with all this sand filtration is a delicate job, and surely none will ever dare to hope that through it perfect sterilization can be reached. When, as for instance, at Rotterdam, the reduction is from 99% to 99½% of the bacteria which the sand filter holds back, this result may well be considered as the highest possible obtainable and is hygienically considered very assuring. But it will not do to close our eyes to every improvement which is offered, and every one who handles the question of sand filtration should embrace every means obtainable to further perfect or aid sand filtration.

“For the sterilization of water numerous chemical means have been recommended, none of which were worth considering in connection with the technical question of water supply. They were either too dear or they changed the quality of the water by introducing foreign substances, which interfered with the consumption. But of all these means ozone has

lately assumed a prominent position, and has been transferred from the laboratory to use in practice, hence, ozone waterworks are successful in improving on sand filtration. If by the use of ozone complete sterilization is not reached its application reduces the bacteria proportion still further.

“As bacteriologist of the waterworks of Rotterdam, I have gladly accepted an opportunity to interest myself with this question, and I am pleased to give my experience in this direction to the public, believing that the water supply is one of the most important problems of the present day, and is of interest to each and every one. In the year 1785”—The article then goes on with a résumé of the discovery of ozone, and then describes the systems of Marmier, Tyndall and Siemens & Halske, and in each case places stress upon the dielectrodes (such as glass) used, and finally, on page 4, describes the

System, Vosmaer

“On this system a waterworks was erected at Schiedam and later in Nieuwersluis near Amsterdam, which latter one is now in daily use. I was pleased, inasmuch as I am so interested in the question of ozonizing of water, to have the company turn the technical control over to me, and with this I have occupied myself lately.

“These electrical experts work with a potential of one hundred volts and a current strength of 20 ampères. This current is changed into 10,000 volts and .2 ampères, or say 2000 volt-ampères. The current changes one hundred times in a second, or 100 alternations. The air is dried through chloride calcium and afterwards measured. One pole of the ozonizer is connected with a secondary high tension current; the other grounded. One pole consists of a row of points which lie opposite the other pole.

“The method of connecting and the apparatus employed in connection therewith prevents any arc formation. No dielectric is used, and concentration of from three to four

milligrams of ozone per liter of air is obtained. The water supply is from the Vecht and is of a very bad quality, and is filtered only through a rapid mechanical filter (System Krönke) to remove the heavier particles. The sterilizer works as counter-current apparatus and delivers from 20 to 30 cubic meters of water per hour, etc.

“One thing is certain that the great advantages of ozonization are readily apparent. The idea of maintaining a good product, allowing the use of any water as source of supply, let alone the smaller ground space for installation required, besides the certainty of an absence of all pathogenic bacteria, is so important that sand filtration, no matter how well it may work, and how careful the supervision of it be, in my opinion, must be inferior to ozonization, and I believe the time is not far off when one of the weightiest questions in the field of hygiene will be fully solved. Even if complete sterilization be not continuously maintained, in some tests made recently by Proskauer and Schuder in Wiesbaden, where the bacteria in raw water was artificially increased by 40,000 colonies per cubic centimeter, the reduction was very great, since in the ozonized water only 16 bacteria remained.

“(Signed) DR. H. J. VAN 'T HOFF.”

“Water Works, Rotterdam, 1903.”

HOW OZONE MAY BE MADE:

Ozone may be made by chemical means and by electrical means. Slow combination of phosphorous causes ozone to be generated, or the heating of silver or gold oxides produces ozone in trifling quantities, but neither these nor any other chemical method has any commercial value inasmuch as ozone can be made by simple methods electrically.

One way is to decompose water which has been strongly acidulated by electrolysis, the oxygen liberated at the positive electrode contains ozone, but the best and most practical way

is to polymerize the oxygen contained in the air by means of an electrical discharge, viz: the so-called silent, dark or brush discharge.

When high tension electricity is allowed to flow from discharges in such a way that neither a spark nor a voltaic arc but only a brush discharge is obtained, then oxygen, whether pure, or as in atmospheric air mixed with nitrogen, will be partly changed into ozone, and thus evidently the only thing required is to provide means for obtaining such brush discharge, and no other, inasmuch as sparks, though they do no harm, will do no good either, and the voltaic arc must be implicitly avoided, or rather made impossible, since its great heat is destructive of any apparatus employed.

ELECTRIC DISCHARGES:

A spark (Figure 1), well known in appearance because lightning is a spark discharge, is a white colored zigzag, loud snapping, oscillatory discharge. Figure 2 is a photograph taken of ten consecutive sparks from a static machine as shown in Figure 1. This discharge is useless for ozone making.

A Rhumkorf induction coil when operated by a high frequency interrupter, such as the Wehnelt or rotary mercury, produces a spark mixed with the violet brush discharge (Figure 3). A voltaic arc, well known in its form in the ordinary arc lamp, furnishes the greatest obstacle, because its intense heat melts anything known.

Figure 4 is a reproduction from a small arc from an alternating current transformer. It may assume a length of several feet; is characterized by a humming sound—a flame-like shape ever changing, and, as has already been said, produces an intense heat. It is a continuous discharge of great current strength, and hence, of great danger to the life of metallic discharges and apparatus.



Fig. 1

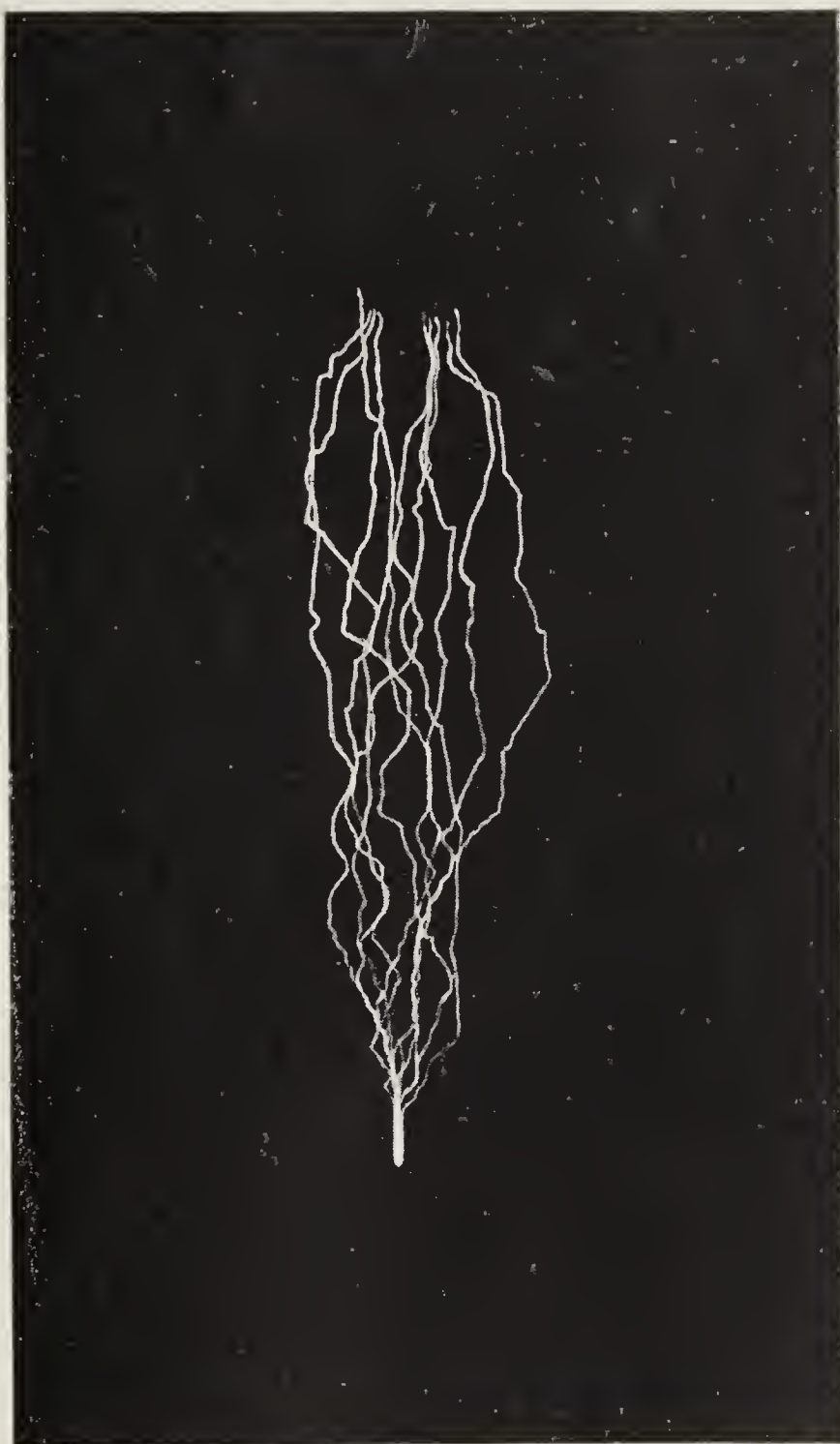


Fig. 2



Fig. 3



Fig. 5



Fig. 6



Fig. 4

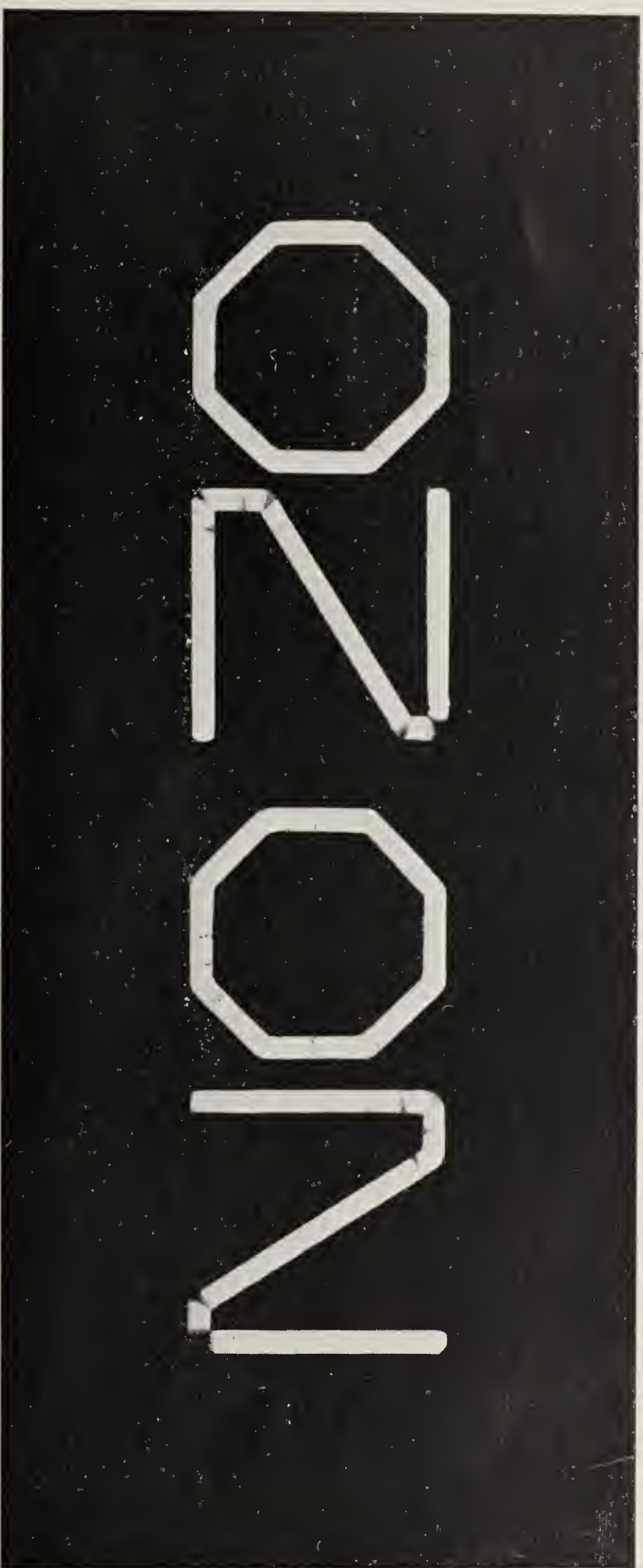


Fig. 7

Quite different from all these previously named is the brush discharge—characterized by a dark blue violet color. It is a convective discharge uni-directional from positive to negative. Figure 5 is a photographic reproduction of a true positive brush discharge, while Figure 6 is the same of a negative discharge—evidently of quite another character. Figure 7 is a photograph of the word “Ozone” in brush discharge (From a high tension transformer of ordinary frequency). It is this particular kind of discharge which causes ozone to be generated. There are five essentially different systems of producing this silent electrical discharge. The first system is based upon the principle that if some solid dielectric (non-conductor) such as glass or mica, etc., be placed between the electrodes or discharger, which are separated by an air gap, between which high potential differences are kept up, neither the spark nor the arc discharge can take place, and the result is that a beautiful silent discharge is maintainable without any interruptions as long as *the dielectric holds*.

Now for the purpose of ozone making nothing of an organic character, such as hard rubber, vulcanite, or the like, can be used, and of all known non-conductors mica, glass and china are the only ones available. Mica, however, does not stand a high dielectric stress. China and also enamel are no good at all, and thus glass only is left over. But, however excellent glass may be, its treacherous behavior under electric stress is well known, and the drawback against its use is its fragility, because suppose an ozone apparatus at work; a beautiful intense brush discharge takes place between one metallic coating and the other; when suddenly, without known cause, a spot in the glass (say an air bubble, or some other unhomogeneity) becomes a little more heated than the rest. As soon as this takes place the glass becomes somewhat conductive; a little more current passes there which causes still more heat, and after a while—it may be a minute; it may be an hour or a day—that particular

warm spot becomes so heated that it becomes a real conductor (which occurs at 400° C.) when all the current strength at once concentrates there and a breakdown is the inevitable result. A voltaic arc is established and unless immediately looked after the apparatus is soon ruined. So great has been this drawback that until lately ozone has never been able to make its way into practical use, because glass apparatus, with the ever present danger of breakdowns, was objectionable to practical men for use on a large scale. It was in 1892 that the great firm of Siemens & Halske, having at that time discovered the remarkable bactericide power of ozone for potable water, promised to bring out, a commercial ozonizing apparatus (see *Elektro Technische Zeitschrift*, 1891, Heft 26, p. 340). Nearly ten years elapsed before they did bring out an ozonizer, but not differing in principle from the one they had in 1891—the same thing again, viz: high potential electrodes separated by glass. In 1901 they came out with an apparatus built up of mirror glass plates, which they claimed to be the very best arrangement for technical use. (See *Journal für Gasbeleuchtung und Wasserversorgung*, 1901, Nos. 30 and 31, and “*die Gesundheit*,” 1901, No. 15); flat glass plates being, according to their publication, superior to glass tubes, and thus that apparatus a great improvement on those formerly used. One year later, 1902, the same firm erected a large ozone plant near Wiesbaden, but “the great improvement” was not employed, and they returned to their old tube system of 1891. (See “*Gesundheit*,” 1902, No. 19.)

Though glass tubes may be tested beforehand and the objectionable ones culled out, still there always remains the fact that the substance called glass is treacherous, as it cannot withstand the ever-changing great electrical stress put upon it, and hence it is unreliable.

It is not worth while to refer to other systems of ozonizers based upon the use of glass, inasmuch as they are all alike—untrustworthy—and none of them have ever been

able to make headway, or have ever been put to practical use. Credit, however, must be given to the firm of Siemens & Halske in that they found a way to somewhat eliminate the difficulty, viz; of subdividing the plant in a number of small units, so that a breakdown of one unit does not mean entire stoppage. All apparatus of the kind referred to had automatic devices for cutting out the current in case of a breakdown of a glass tube (a strip of blotting paper holding a spring, and when the paper gets water soaked it gives away, releasing the spring which cuts off the current). Moreover the glass tubes are water cooled (with water of 60° C.) and numberless automatic cutouts, check valves, etc., are provided to prevent great mischief; in other words, reliance must be placed upon the much discussed and doubted reliability of automatic arrangements.

Andreoli, Abraham-Marmier, Yost, Yarnold, Lamprey, Friedham, and all the others, use a dielectric and hence cope with an unreliable quantity.

The second system (it may be called a system because it differs in principle from the others and not merely in make) involved the use of high frequency current—sometimes called Tesla currents. The effect of high frequency currents on the character of electric dischargers to obtain brush discharges and nothing but these, *i. e.*, no sparks or arcs or difficulty whatever, is marvelous. No dielectric is needed, but the system of high frequency currents involves difficulties commercially which makes it prohibitive, as the efficiency electrically considered is very low, *i. e.*, only a small part of the energy produced is converted into brush discharge; besides, the high frequency brush discharge gives very little ozone when compared to that generated by the ordinary brush discharge.

The third system is that of Tyndall. Tyndall uses no dielectric whatever, but interposed in the circuit a high resistance, such as a tube filled with glycerine showing something like 20,000,000 ohms resistance. He starts with

ordinary alternating current transforming up to 40,000 or 60,000 volts, leads this to the 20,000,000 ohms resistance and then to the dischargers proper; these being made of very fine platinum wire gauze set on end so as to furnish many fine points.

This system certainly has the advantage of being an improvement on the former systems, but has the disadvantage of furnishing a very poor efficiency in ozone yield; moreover it cannot be worked without artificial cooling (down to -25° C.), and requires careful attendance, because after all the high resistance does not prevent arcs; it only prevents sparks.

In the Vosmaer system there are no solid dielectrics between dischargers, neither high frequency nor high resistances nor rotating electrodes, but the brush discharge is produced by using sharp pointed dischargers against flat electrodes and the voltaic arc by a special way of connecting up, is absolutely prevented. (See Figure 8.) In this diagram, T is an ordinary step-up transformer, C is a high tension condenser, L is a high tension choking coil, and O is the ozonizing apparatus. The high tension alternating current from T is shunted by the condenser, while the choking coil is in series with the line. In this way an arc discharge at O is an absolute impossibility. The ozonizing apparatus *per se* is simplicity itself. There are no moving parts; no fragile material is employed and no cooling whatever is resorted to. The ozonizer consists (Figure 9) of a number of tubes put together something like a feed water heater. In each tube, *d*, there is a complete set of dischargers, viz: one flat, *a*, and one pointed, *b*, (see Figure 10) separated from each other at a fixed distance by insulated stems and forks, *c* (made of porcelain). There is nothing out of the ordinary about the transformer or choke coil, but the condenser is of special manufacture. Its general outline is shown in Figure 11, and if made with care it never gives rise to the slightest trouble whatsoever.

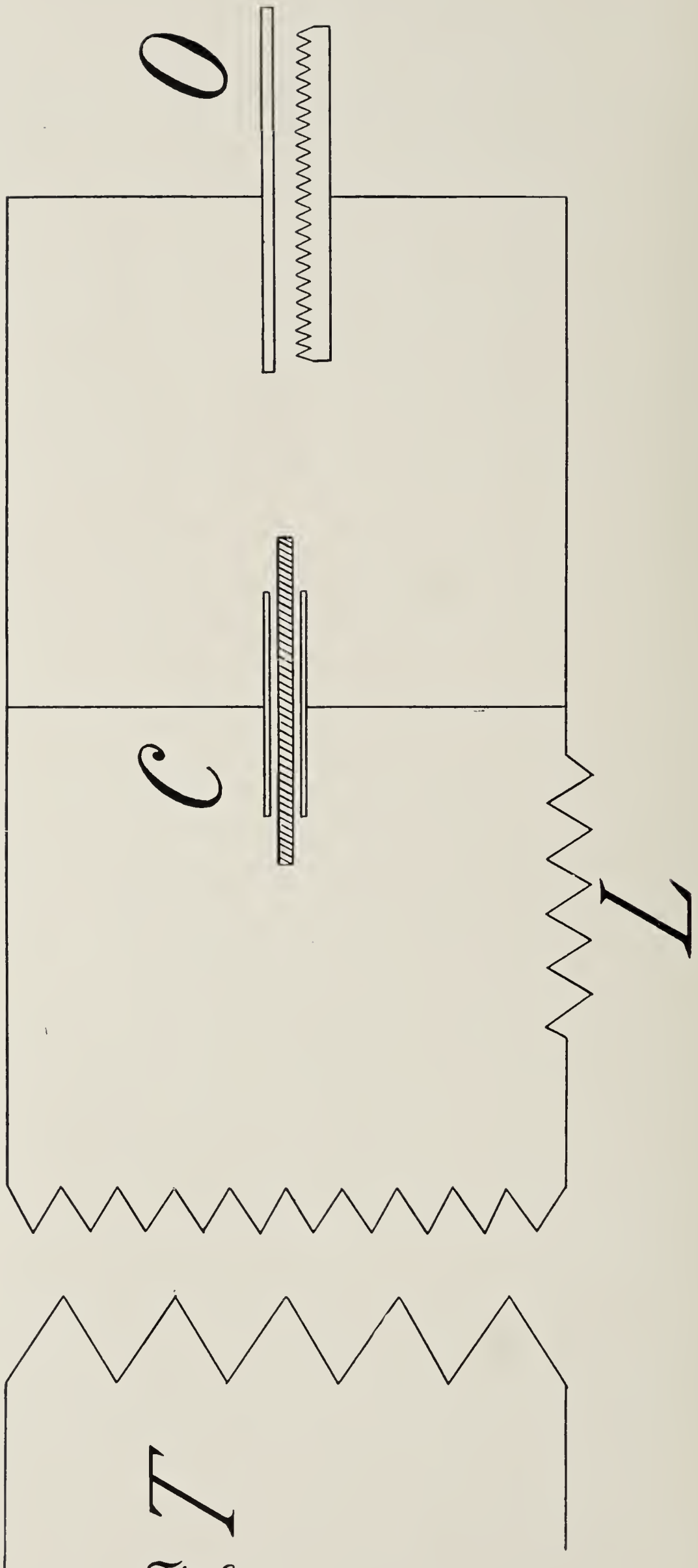


Fig. 8

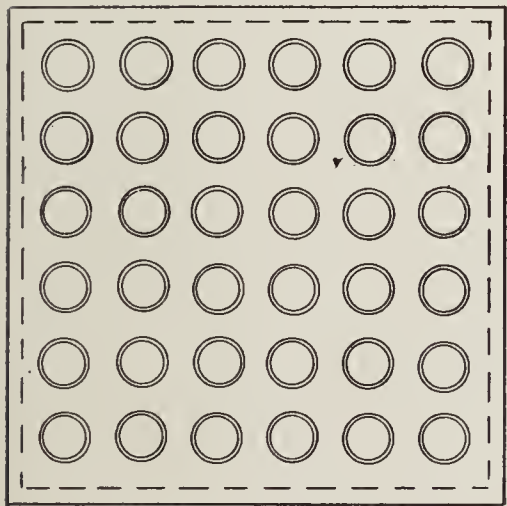
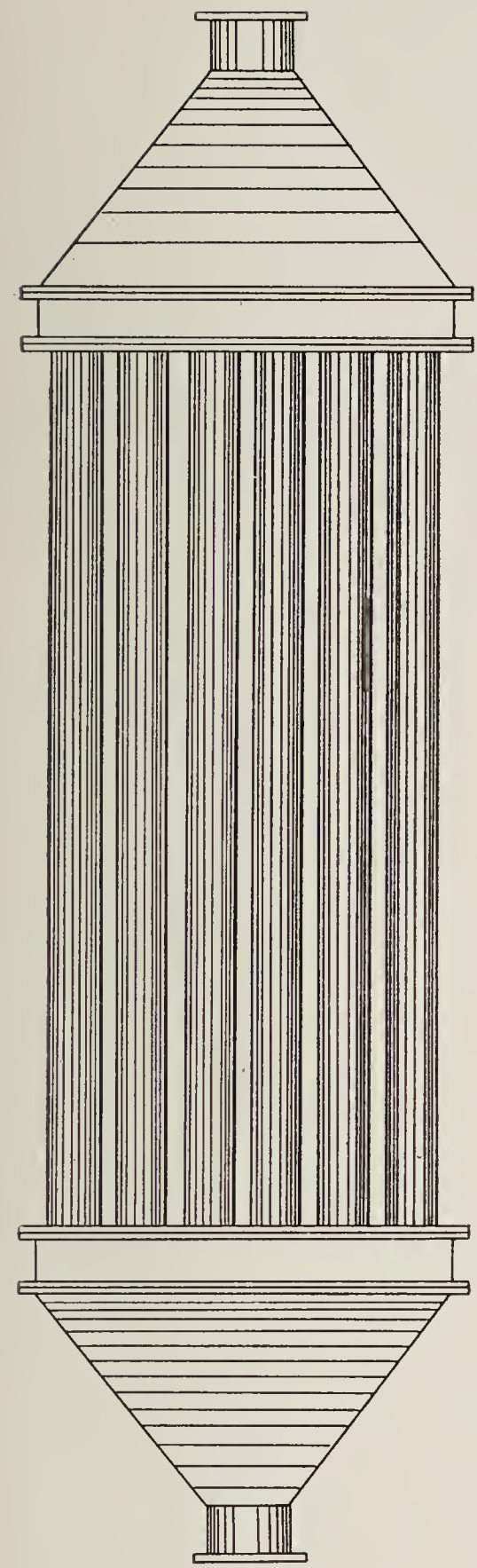


Fig. 9.

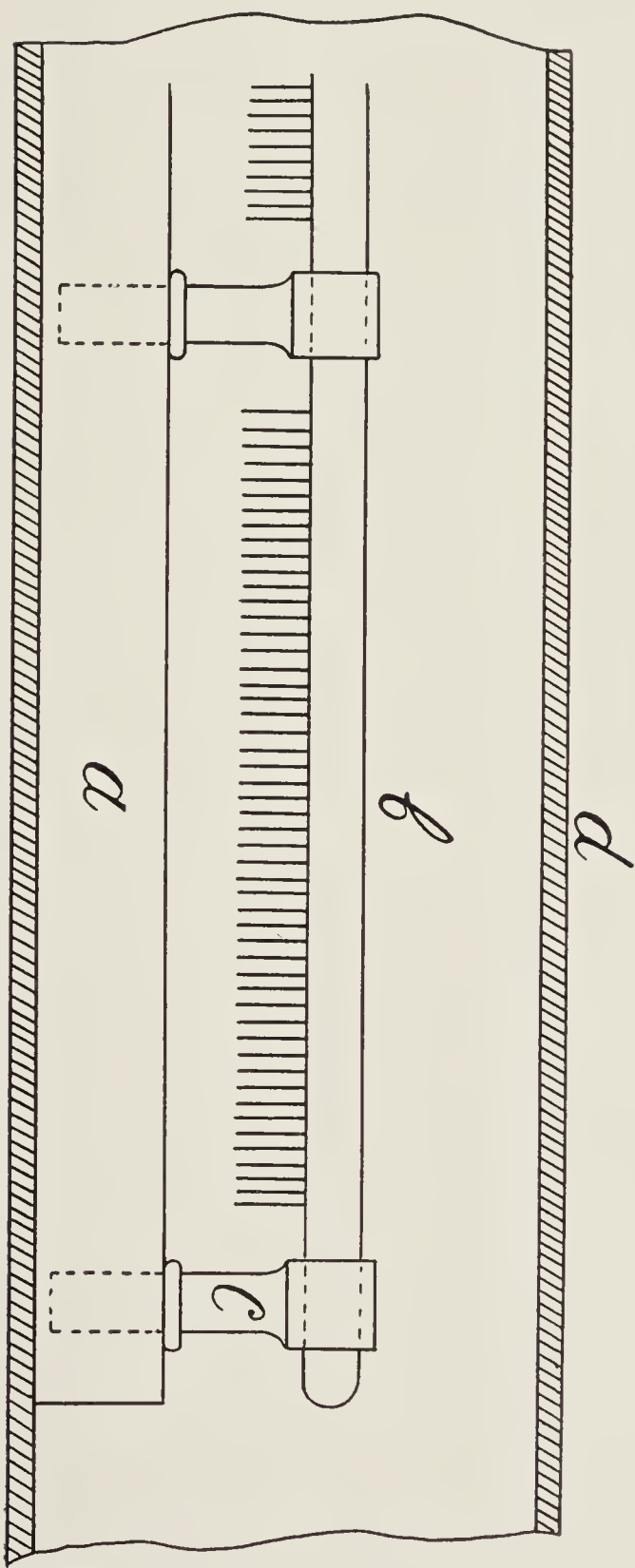
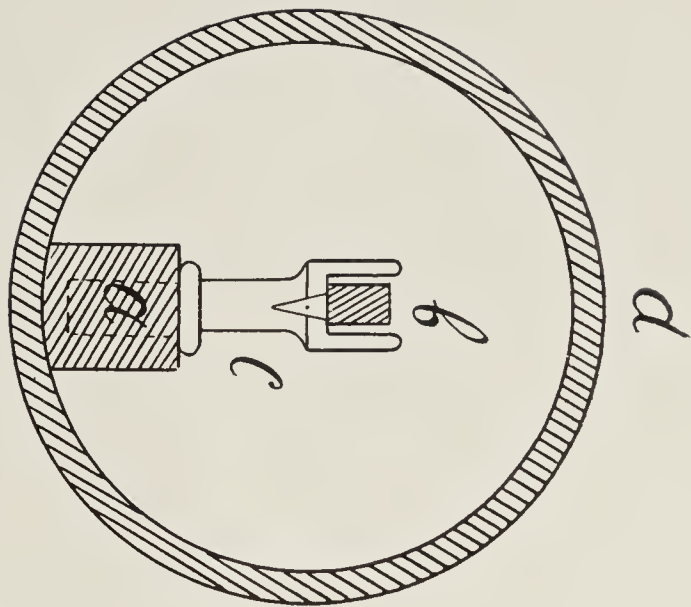


Fig. 10.

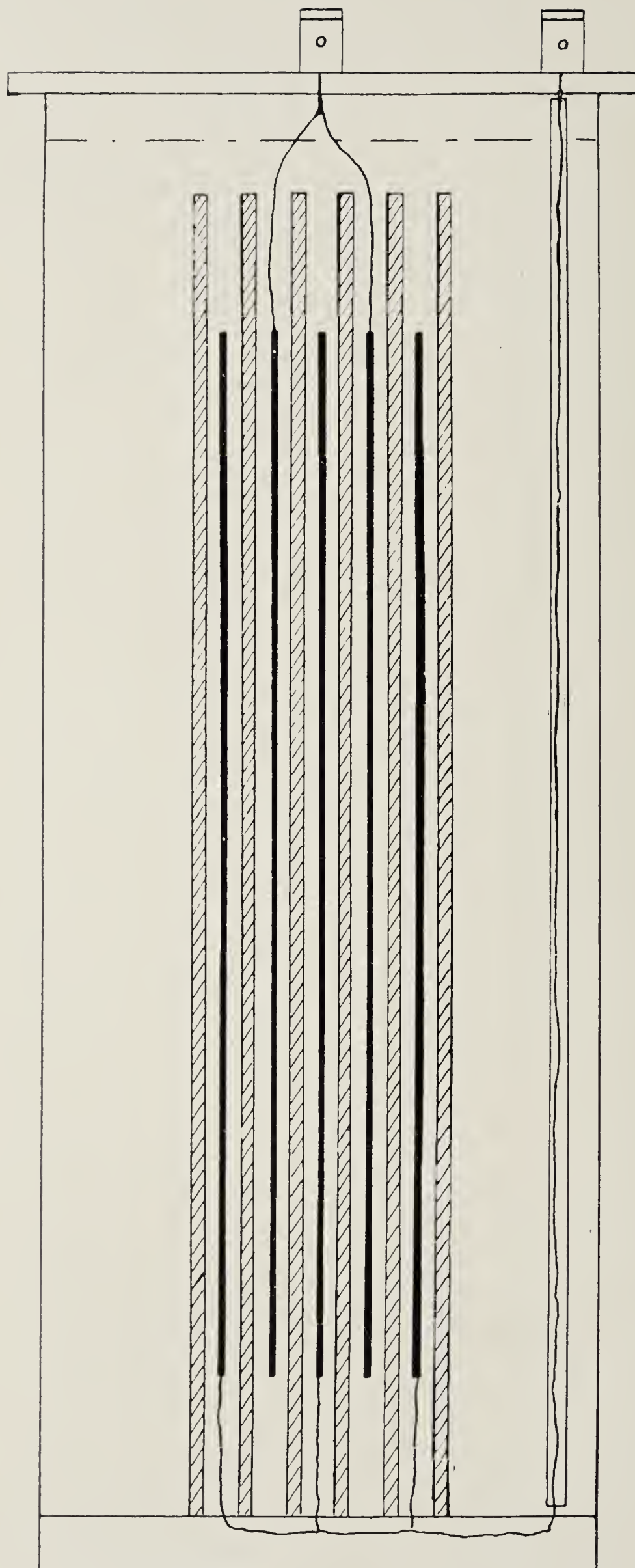


Fig. 11

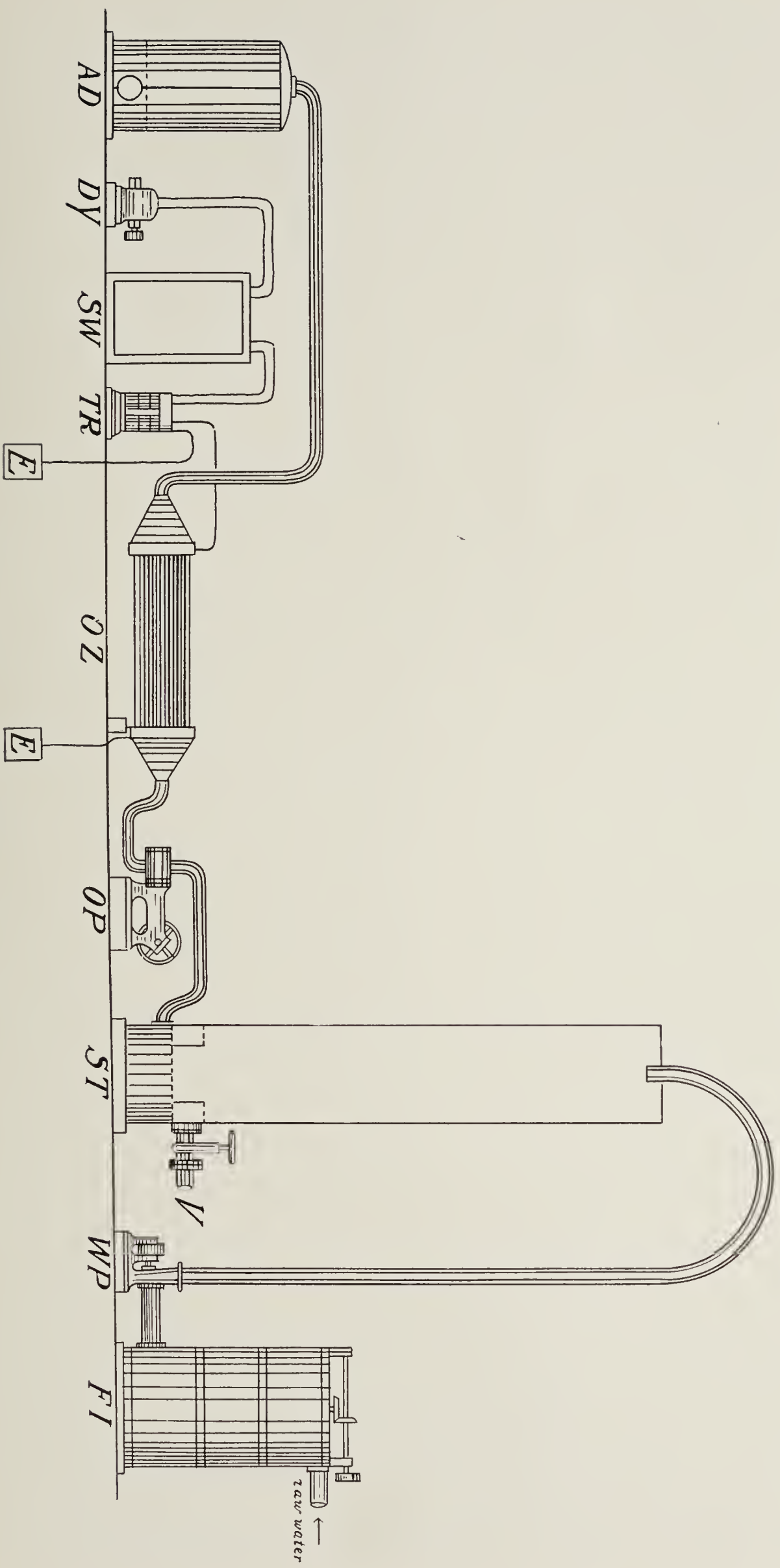


Fig. 16

F1 means the rough filter from which the water by means of the pump Wp goes to the top of the sterilizer St and leaves by the valve V. The air enters through the air drier Ad, goes through the ozonizer Oz, and by means of the pump Op is forced into the bottom of sterilizer St.

An ordinary generator Dy delivers its alternating current to a switchboard Sw from whence it goes to the step-up transformer Tr (earthed), and from here to the ozonizer apparatus Oz (earthed).

Figures 12, 13, 14, 15, and 16 are from photographs of the Nieuwersluis plant.

When once properly started the plant requires hardly any attention. The only question of importance is the determination of the amount of ozone required for the particular water to be treated (to provide a sufficient quantity of ozone). There are two methods for determining whether the quantity of ozone supplied be sufficient or not. First, by testing the surplus of ozone at the outlet of tube 4; by iodine of starch paper. Second, by the sense of smell. As long as there is ozone left it is certain that there has been sufficient to destroy the bacteria, and if more absolute certainty is desired, there is still another way, viz: determining by chemical means the quantity of soluble organic matter oxidized. Experience, however, is a safe guide, and there is no special skill required at Nieuwersluis to run the plant. Any engineer of ordinary intelligence can do so.

The claims made for the high efficiency of sand filtration and especially slow sand filtration, may not be challenged in the face of the magnificent results obtained both in this country and in Europe, for it must surely be conceded that a reduction by slow sand filtration of over 98% in the number of bacteria present in the raw water before filtration is a splendid showing, and the remarkable reduction in the number of typhoid fever cases, wherever sand filtration has been introduced, speaks volumes. Scientists, however,

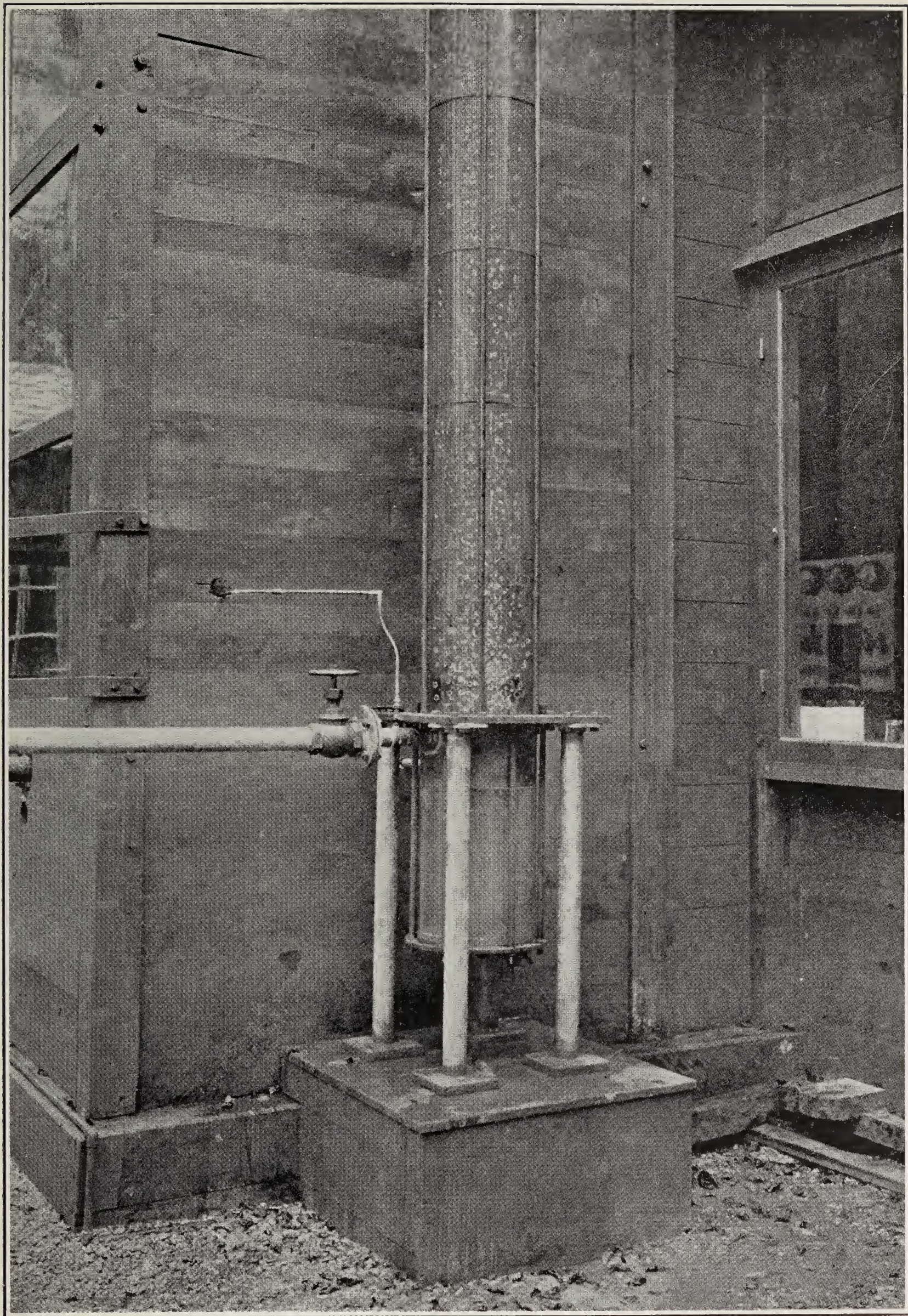


Fig. 12. The Standpipe

will not be satisfied with the words, "reduction of," but instead insist upon total elimination. It is unnecessary to dwell on the material loss involved in the appalling annual death rate from typhoid fever and other diseases traceable to impure water, the grief and misery consequent thereon alone appealing to every human heart.

That the biologic action of any filter system, *per se*, is not continuous and uniform in efficiency, none can deny, and that in any filter system it is a question of reduction in number of cases and not of complete cessation, is also a matter of common knowledge, and again, clarification with partial purification, and clarification with total purification are two different things.

It must be admitted that by boiling the water after filtration sterilization is produced and all danger from pathogenic germs avoided, but, then, it must be apparent that if boiling is necessary after filtration, the filtration may be accomplished by what is called rough filtration only; and further, the means required for the boiling act are not always readily at hand, and it is well known that danger signals do not always prevail.

The following article is from the London, England, *Evening Standard*, of March 2, 1904:

WATER FILTERING.

"In very few directions has recent science revealed anything more curious and interesting than in that which has to do with the purification of water, of which Londoners have, in one way or another, been hearing a good deal more than has always been pleasant. Singularly enough, although the eight London Water Companies have long been filtering river water on a vast scale, and, it may be presumed, have for many years been closely studying the subject, the latest advances in the science of filtration appear to have resulted, not from any experiments with the comparatively pure water of the open river, but from the necessity of purifying the



Fig. 13. Standpipe and Ozonized Water Basin

effluent from London sewage. There have been three clearly distinct stages in the science of filtration, and two out of three are quite modern, indeed the last of them may be said to have been only quite recently attained. When the first of these three stages was arrived at the world must have been much younger than it is now. It must always have been obvious enough that water containing any kind of foreign matter, such as fallen leaves, must necessarily have it eliminated by passing through a bed of gravel or small stones. It is, of course, a mere straining process, and must have been recognized as a means of purifying water almost as soon as men were capable of discerning the difference between clean and dirty fluid. But though the mere straining of water must have been known to be a means of purifying it in the very early days of civilization, it was only within living memory that the second stage in the science of the thing was attained. For untold ages it was supposed that the filtration of water was a process of mere mechanical straining, and the London filter beds, about the efficiency of which so much has lately been said before the Board of Arbitration and elsewhere, were all originally laid down on this rudimentary theory. Many middle-aged Londoners will very well remember the outcry which led to a totally new theory on the subject. The Thames at Westminster was in such a foul condition that the windows of the House of Commons had to be kept closed because of the stench. At the same time, only a little higher up the river, water was being drawn off for the household supply of Londoners. There was an outcry that led to close investigation. Experts were employed to analyze the water in the river and the water in the Companies' mains after passing through the filters, so as to see what had been actually eliminated. The next thing was to examine the intercepted matter left in the filter beds, and then a very curious fact came out. As it was only a process of straining out impure matter from the river water, it was to be assumed that all the extracted impurity would be found

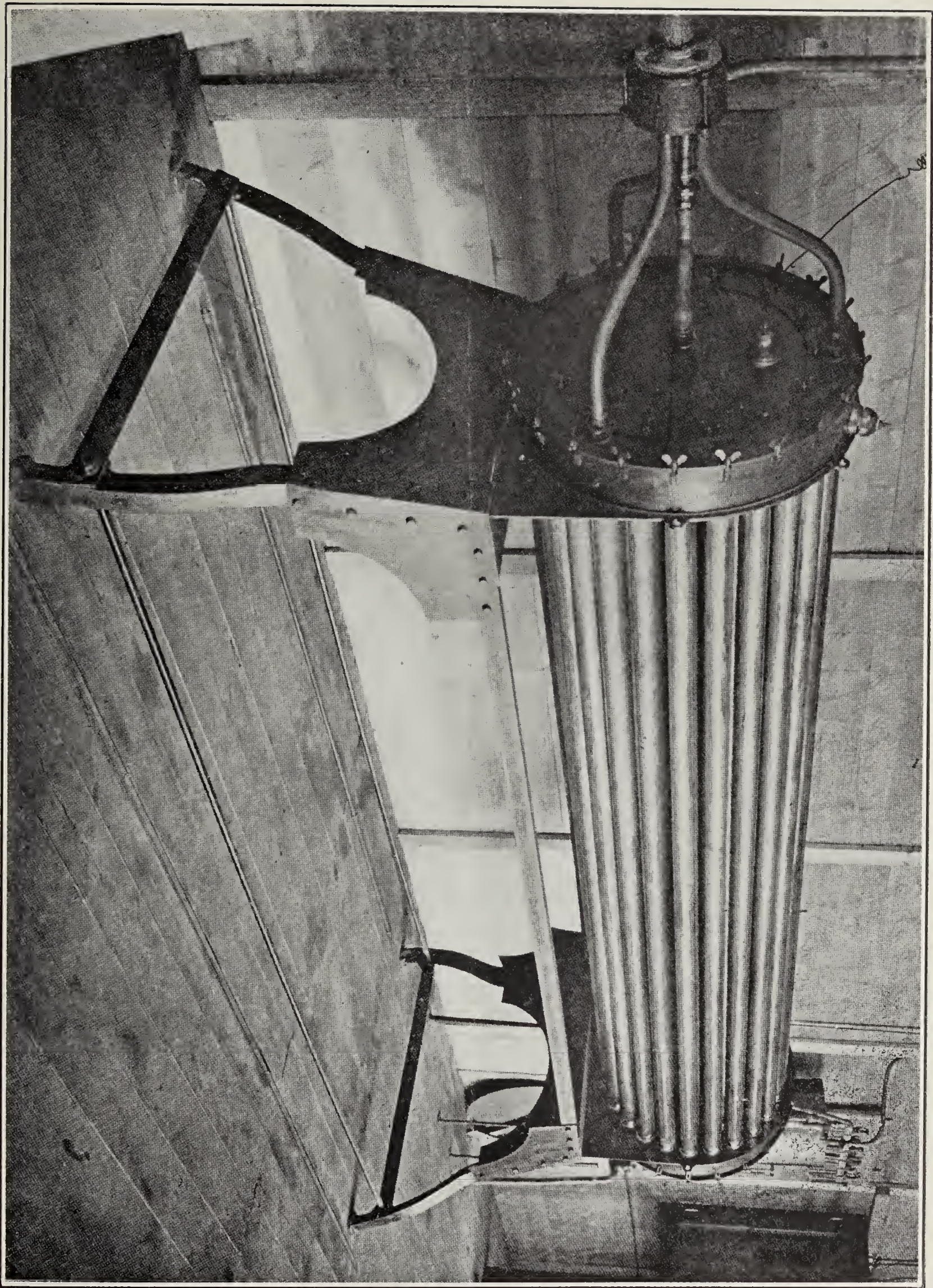


Fig. 14. The Ozonizer

in the strainer. But, as a matter of fact, it was not all found in the strainer. A very large part of it had totally disappeared. What had become of it? The endeavor to answer this question soon made it apparent that the efficient filtration of water depended not only on the mere straining powers of the filter but on a process of chemical decomposition also, and that the efficiency of a filter depended on its power of promoting this chemical action, as well as upon its mere mechanical action.

“This was an entirely new idea, and scientists were soon able to explain the matter. A filter bed, as constructed by the London companies, was a porous mass of stony particles—pebbles, coarse and fine gravel, broken shells, sand, and so on—and around every particle, even the most minute, there clung a film of condensed air. In passing down through the bed the water and the impurity it contained were brought into close contact with these tiny films of air, and the consequence was that organic impurity—all sorts of animal and vegetable matter—was oxidized. That is to say, the organic impurity entered into chemical combination with the oxygen of the air—just as a candle does—and was burnt up—just as a candle is burnt up. That, of course, explained the mysterious disappearance, and the new theory of filtration was permanently established. The aëration of water is in fact its greatest purifier, whether the aëration is effected in a clean, fresh filter-bed, or by tossing the fluid into the air in a fountain spray, or by tumbling it over a rocky cascade. However impure river water may be at one point in its course, and whatever be the nature of its impurity, only let it go rippling through the open air and foaming over rocks, and it will gradually lose all its pollution. But the investigations that led to the establishment of this second theory of filtration started another difficulty which the aëration idea was incapable of explaining. If water-filtering had been only a matter of straining and aëration, then the cleaner and fresher the filter bed, the better it would have done its work. But every-

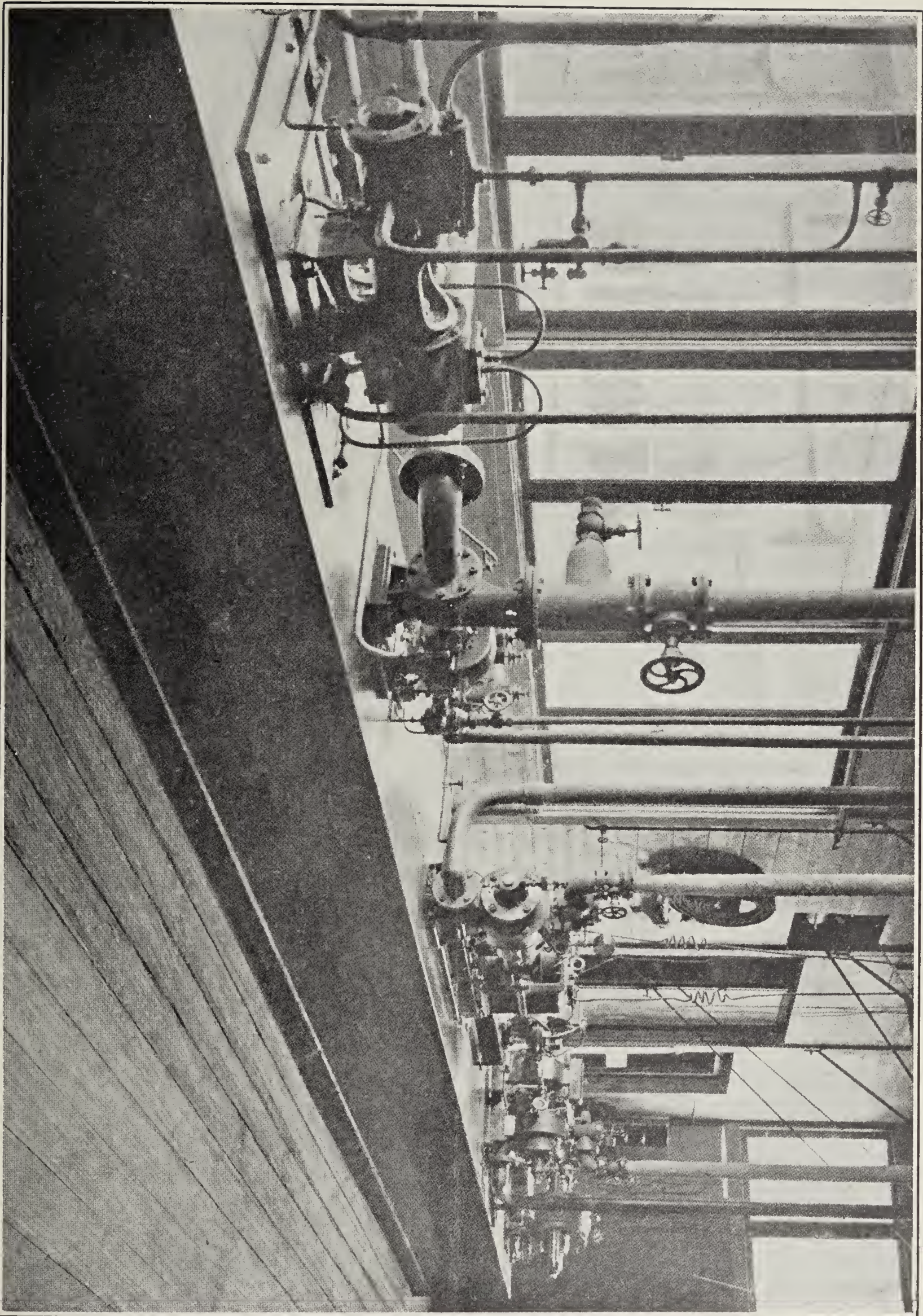


Fig. 15. Air Pump, Generator, etc.

body was much puzzled to find that as a matter of fact it was not so, and there were many cases in which, yielding to the urgent remonstrance of the Local Government Board, the Water Companies had cleared out their dirty beds and put in others clean and fresh, only to find that the clean new beds were not so efficient as the old dirty ones. Besides mechanical interception and chemical absorption, there was clearly something else involved in the operation.

“Seventeen years ago some idea of the truth of the matter had begun to dawn as a result of the work of Pasteur, Koch, and others, and Mr. Didbin, the chemist of the County Council at that time, very clearly expressed his belief before the Institute of Civil Engineers that, in addition to the mechanical and the chemical, there was a biological factor in the matter, though at that time knowledge, he said, was not sufficiently advanced to permit of any biological theory being put to practical application. What seemed pretty certain seventeen years ago was that bacteria and others of the lowest forms of life had something important to do in eliminating impurity from water, and as time went on and American chemists as well as our own took up the subject, so much was found in support of the new science that ten or eleven years ago the thing was put to practical test by laying down a new bed specially designed to enable microbes to show what they were capable of. The new filter was not intended for the purification of river water, but of sewage water running out from the subsiding tanks in connection with the London main drainage system. If these little bacterial philanthropists could deal with this effluent water their cleverness and usefulness would require no further test. As a matter of fact they came out splendidly. The beds were composed of a certain thickness of coke breeze, and through this the foul effluent water was passed in gradually increasing volume. Gradually the bacteria increased in number and in the same proportion the filter beds increased in efficiency. The result showed—what is always so satisfactory to have shown—that

the past had not been all wrong, but only incomplete. Practice and theory had both been right so far as they had gone. A well-made filter bed did act mechanically, as it had been supposed to do, and it did act chemically also; but the chemical action required to be promoted and assisted by the efforts of the microbes, and it became apparent that the reason why a new filter bed did not filter water so thoroughly as an old one was, that there were no bacteria to assist in the business. The oxidation of decayed animal and vegetable matter, it now appears, depends under certain circumstances, upon two minute forms of animal life—one of them requiring an abundant supply of fresh air, the other finding all it requires for health and happiness in the densest filth it can find, and apparently without the smallest need of any atmospheric air at all. In the foulest mass of putrefactive corruption it will live and thrive, and will break down highly organized animal and vegetable substances into simpler forms of matter capable of being appropriated by the fresh air microbes, or of entering directly into combination with the fresh air of the filter-bed or the water-fall. Thus filtration was first of all mechanical, next chemical, and has now become to a large extent a factor of animal life and activity.”

Abstract of remarks made at the Sanitary Conference of the Health Officers of Connecticut, at New Haven, December 17, 1903, on “The Failures and Possibilities of Water Filtration,” by Allen Hazen, M. Am. Soc. C. E., from *Engineering News*, December 31, 1903:

“Most of the filters that have been installed in this country have failed at times more or less. Some of them have failed habitually and disastrously. With others the failures have been occasional and slight, and some have not failed at all. By failing I mean that water has been sent out from them falling considerably short of the standard of purity established by reasonably well constructed and operated filters. This definition may be a little hard on some of the older plants, for nearly all of them have served to improve materi-

ally the quality of the water which has passed them, and to this extent they have been successful. I am considering the matter, however, from the standpoint of the most exacting requirements of the present time, and from this standpoint these plants cannot be considered as entirely successful. These shortcomings of filters have been widely advertised, and as I say, have greatly limited the extension of a most useful process. Progress is often made by a study of failures, and I want to talk to you to-day about the reason for these failures; and why, as I believe, the fact that there have been failures should not be given too much weight in considering the application of the process to new problems.

“Let us consider briefly what the causes of the failures have been. They can all be divided into two classes, namely, those resulting from defective construction, and those resulting from defective operation.

“Under the first head we have, first, the defective results which are obtained from filters of old designs. There are still in the United States many filters, built before the art of water purification was much developed in this country; and while some of these old filters were of surprisingly good design, considering the time at which they were built, and have been and still are doing good service, there are many others defective in important particulars, and so far failing to represent the conditions known by modern experience to be essential to success that the results obtained from them are very inferior. In some extreme cases the water is hardly purified at all, and the filtration might almost as well be abandoned.

“As the second cause I will mention inadequate construction. By this I mean the cases where filters are provided of too small capacity for the work to be done, or where, in order to save money, the appliances provided are materially below those demanded by standard practice. This has been, and still is a very important element in unsatisfactory results from filters.

“As a third cause we have the blind copying of designs successfully used elsewhere. There have been many failures in American filters coming under this class, that is, by injudicious applications of good designs.

“As the last head under defects of construction, I place experimental construction; and this is by far the hardest one in the series to guard against successfully.

“Nearly all filter designs are to some extent experimental. That is to say, it is still impossible to reproduce a plant and all the conditions under which it operates in another locality. There is always something new, for the general practice of water purification has reached such a state that for very large range of waters, a range so wide as to include most of the waters used for public water supplies in the United States, filters can be selected which much resemble filters which have been successfully used for the same kind of water elsewhere that the experimental element in construction is reduced to a minimum.

“If all experimental construction should be shut out, the art of water purification would become stereotyped, and this is certainly not the result that we are looking for. But, on the other hand, it must be frankly admitted that a large part of the failures in water filtration have resulted from experimental construction.

“The conservative and rational course seems to be to adopt in important new constructions only such improvements as are of a type to allow of very complete and certain analysis; and when it seems advisable to make other and more radical changes, the effects of which seem promising, but which cannot be told certainly in advance of trial, they should be used only in a small and tentative way, or they should be examined by experiment made for that purpose in advance of actual use.

“When cities have built filters founded on entirely new processes, differing radically from the lines of approved practice, as a few cities in this country have done, the results in

some cases, I think in nearly all cases, have been complete failures.

“The second class of failures are those due to defects in operation. Of these many come from lack of proper attention. The filter is put in the hands of some one who does not understand it, or who does not know the importance of maintaining proper operation, and it is neglected at some time, or even habitually, and the results fall off in consequence. Sometimes the failure in operation comes from the desire to economize. This happens most frequently in those filters where chemicals are used as an aid to purification and where a direct saving can be made by using amounts of coagulant below the amounts necessary for the best efficiency.

“I hope that I have made it clear to you that these causes of failure are precisely the same as those which cause failure in any undertaking and that they can be eliminated and guarded against by the same kind of precautions that are necessary to success in any business.

“The risk of using the water from a filter plant should be as little as the risk of traveling upon a train; in fact, it should be less, for the opportunities for control and safeguard are greater; and it can be arranged so that the chemist takes sample of the water from a point entirely beyond the control of those in charge of the filters, and examine such sample so frequently as to enable him to detect any failure to accomplish the desired results from any cause whatever; and we may be sure that the man at the filters will not put himself in the way of being caught napping under such supervision.

“Experience demonstrates that this can be accomplished. In Europe there are many filter plants operated on this basis. In this country there are few. From these plants water of the very best quality is uninterruptedly supplied year in and year out without a break, and with as little chance of failure as there is in the use of almost any appliance in common use. The number of such plants is increasing and will increase, and as time goes on, and as the subject is better understood,

and is understood by more people, the plants that are insufficient and badly designed, and inadequate because out of date will be gradually replaced by better ones; and the superintendents and foremen who are not faithful and careful will be superseded by better educated and more careful men.

“I want to emphasize to you to-day, gentlemen, that what is needed in water purification plants is not so much new processes and better processes as more careful and intelligent and faithful application of the processes that we now have.

“The efficiency of filtration is well illustrated by the history of the water supplies of Paris and its suburbs in the last two decades. Paris has long had a supply of spring water, brought through aqueducts from distant sources—aqueducts comparable in their size and cost to those wonderful aqueducts which supplied ancient Rome. The quality of this spring water was regarded to be the very best. The unfortunate feature of the situation was that there was not enough spring water for all, and it was necessary to supplement the supply at times by pumping river water into the pipes. Typhoid fever was prevalent in Paris and was believed to be due to this mixture of river water.

“In 1830 Paris completed a new aqueduct, bringing in some entirely new springs of large capacity and for the first time in a good many years there was enough spring water, and it was no longer necessary to pump river water into the pipes for domestic use. After this the typhoid fever rate in Paris decreased very rapidly. When Paris grew beyond its bounds, and suburbs developed with a population of several hundred thousand, these suburbs were not annexed because there was not enough spring water to go around; and Paris was unwilling to divide with them. These suburbs were entirely unable to secure a supply of spring water of their own. The next best thing available to them was to use the river water with filtration, and filters were established at several points by the company supplying them; and these filters

were put in operation at about the same time that Paris secured sufficient spring water.

“There were then these two bodies of population; Paris the inner city, supplied entirely with spring water, and the ring of suburbs outside supplied by filtered river water; and it was soon noticed that typhoid fever was much less prevalent in the suburbs than it was in the city. Thus when the two kinds of supplies were put to the ultimate test the filtered river water proved better than the spring water. For the last few years a commission composed of many of the leading scientists and engineers of Paris have been considering this question, and it has found pollutions entering the springs so numerous and so great as to amply explain the higher death rate among the users of this water. It has been possible to shut off some of these sources of pollution, and some of the springs have been excluded and filters have been built to make up the deficiency with filtered river water, and the conditions are thus improved, but the matter of entirely correcting them is difficult. It has been proposed to filter the spring water supplies, and other and new sources are under consideration, but no decision has been reached as yet.

“At the present time there seems to be a source of arbitrary standard in the methods of water purification. That is to say, methods are extensively used which make the cost of purifying a million gallons of water, including interest and sinking fund charges, somewhere in the neighborhood of \$10, and which are sufficient to remove 99 or 99½% of the bacteria of the applied water. This may fairly be called the best practice to-day. A purification like this serves to furnish a water from the Merrimac, or from the Hudson, in every respect as good, and perhaps better than is obtained from the best upland sources. It would be difficult to produce sufficient reasons and to back them up, to induce a water board or City Council to authorize the necessary expenditure to produce a much more complete purification than this, but it is important to keep this matter in sight, and to note that, if

the pollution of our rivers increases, the purification can be made to keep pace with this increase, and it will be possible to obtain water of the best quality, even though conditions become far less favorable than they are to-day.

“The triumphs in the past have been great. The typhoid fever death rates in a number of cities have been reduced by the installation of filters by 70% or 80% or more. General death rates have also been reduced by amounts which correspond to much more than the reduction in the typhoid fever rates. Perhaps the achievements of the future in this respect will not be more striking than those in the past, but this certainly is true, that with the gradual raising of the standards of the quality of water supplies, and with the growth of a desire for cleaner and purer water, the art of water purification will advance and its application will be constantly extended, with the greatest benefit to the people of our cities.”

Some Lessons of the Butler Typhoid Epidemic.

From *Engineering News*, December 31, 1903.

“Hard as it is upon fever stricken Butler, the typhoid epidemic in that community may be the means of saving thousands of lives elsewhere by directing public attention to the dangers of polluted water and inefficient sanitary administration.

“We say thousands of lives advisedly and with full knowledge that the total number of deaths in such epidemics as that of Butler or at Ithaca fall far short of any such number. The fact is that the great mortality from typhoid fever results from the numerous cases which are occurring all the time in all parts of the country without the disease becoming sufficiently prevalent to be called epidemic.

“In the past twenty years there have been only two typhoid epidemics comparable with that of Butler, viz: Plymouth, Pa., in 1885, and Ithaca, N. Y., a few months ago. The total number of recorded typhoid cases in these three epidemics will probably be somewhere near 3500 to 4000 and

the recorded deaths three hundred or more. Meanwhile not a year has gone by when thousands upon thousands of persons have not been stricken and many thousands died on account of the pollution of the public water supplies of the United States. In other words, the great water-borne typhoid epidemics have been few and at long intervals, but there are numerous cities with polluted water supplies in which typhoid is always prevalent. Thus it is not merely to avert the danger of epidemics that thousands of American communities need radically to reform their sanitary conditions. Such action is needed to eliminate the cases of typhoid which occur every year and often at all times of the year. What at first thought may seem to be a sweeping condemnation of private ownership of water works is a fact that the three great typhoid epidemics at Butler, Ithaca and Plymouth were all caused by water supplied by private companies. But on the other hand, what shall be said of the equally striking fact that municipal-owned waterworks head the list of cities with continuously high typhoid mortality? For the years 1898 to 1901, the City of Pittsburg, most of whose population is supplied with water from city works, had an average typhoid mortality of 113 per 100,000, standing at the top of the list of cities of thirty thousand and upwards. Charleston, S. C., under private ownership, came next (110), but was followed by three cities owning their works, namely: Youngstown, O.; Allegheny, Pa.; and Troy, N. Y. (109, 90 and 90 respectively). It would be interesting, and perhaps profitable, to go all through the list and see how the ownership stands as the typhoid mortality lowers, but our present space and purpose will not permit such an analysis. While there is reason to believe that a pure water supply can be more readily secured and maintained under municipal ownership, it is at the same time true that polluted water is now being furnished by hundreds of waterworks, including which are very many works owned by cities as well as those owned by private companies.

“Even in cities where radical changes in the waterworks are not needed, there is frequently urgent need for a thorough sanitary study of the water supply, to be followed by constant sanitary supervision, all under the direction of technically trained men.

“To inaugurate such sanitary reforms there is needed not only action by the towns and cities but by State authorities. It is not difficult to trace a direct connection between the epidemic at Butler and the fact that Butler is located in the State of Pennsylvania. That State, to put matters plainly, is well known among sanitarians to be notably backward in all matters concerning the protection of the public health. This is not a mere matter of opinion. It can be shown by statistics which represent human lives.

“In order to show by concrete example what sanitary neglect in Pennsylvania really means, let us compare the records of typhoid fever mortality in its cities with those of cities in Massachusetts, a State much more densely populated, but well known the world over for its advanced position in matters of sanitation. Among the cities of the United States having 30,000 population and over for which typhoid mortality statistics for the four years 1898 to 1901 are available, Pennsylvania has 15 and Massachusetts has 17 cities. Nearly all the Pennsylvania cities are among those of high mortality and every one of the Massachusetts cities is among those having low typhoid death rates. The total range of the table, it may be added, is from the very high rate of 113 to the low rate of 6 deaths per hundred thousand of population per annum.

“Pittsburg heads the table with 113 typhoid deaths per annum, and Allegheny comes fourth with 90. Johnstown stands six and York ninth, making four Pennsylvania cities among the first ten. The four Pennsylvania cities in the last half of the table stand number 67, 75, 94 and 95, the last two being Erie and Scranton, each with an average typhoid mortality of 25 per 100,000.

"In Massachusetts, New Bedford shows an average mortality of 30 per 100,000, Boston and Springfield showing an average mortality of 26 per 100,000.

"To what shall the vastly superior showing of the Massachusetts cities be ascribed? The records of the past show that it is due almost wholly to the relatively high character of the water supplies and to efficient sanitary administration.

"Several years ago a number of Massachusetts cities were notorious for their high typhoid death rates; but the work of the State and local Boards of Health, backed by sound public opinion, has largely remedied former evils and has made the State foremost the world over for its efficient sanitation. The work of the Massachusetts State Board of Health in lessening water pollution and solving the problem of sewage and water purification has been recognized by the sanitary experts of all civilized nations as one of the most notable advances in public sanitation ever recorded.

"Contrast with this record the record of Pennsylvania. Among sanitarians, foreign and American, the State is chiefly notable as an example of the results of sanitary neglect.

"For decades the great city of Philadelphia has had to drink the foul waters of the Schuylkill and Delaware, and thousands of lives have been thereby sacrificed. Only now, after a generation of agitation and delay, has the city entered upon the construction of filtration plants to purify its water supplies.

"Pittsburg, which, as we have stated above, has long been notorious for its high typhoid rate and is now suffering to an extent which almost assumes the proportions of an epidemic, deserves credit for having a few years ago expended a large sum of money in water purification experiments. It deserves nothing but discredit, however, for ignoring these experiments and delaying the work of water purification. Its citizens suffer and die by the hundred, while rival politicians and contractors struggle for party advantage

and personal gain in connection with the proposed construction of filtration works.

“Allegheny, so far as we can learn, also continues to pay a heavy penalty for impure water, notwithstanding the huge filter crib at its Allegheny River intake, which it constructed at great expense a few years ago.

“Reading, standing No. 33, or just below Philadelphia, in the list of cities already reviewed, is making some progress towards the introduction of filters, but its past record is not one to be proud of. At Chester the water company has installed filters, but it appears to have been driven to do it by litigation.

“It would be interesting to inquire to what extent the backward sanitary condition of Pennsylvania is due to its local municipal government or to its State government. Undoubtedly both are deserving of extreme censure. The State Legislature has not been liberal in its appropriation for the State Board of Health, nor has it clothed that body with the powers which it needs to carry on a fight against water pollution. Moreover, unless by quite recent legislation, needed powers for the conservation of the purity of public water supplies has not been granted to either local authorities or water companies. With such a record is it any wonder that Pennsylvania has to its debit two of the three great typhoid epidemics which have occurred in this country or that most of its large cities have for years reported heavy mortality from typhoid?

“It may be said in defense of Pennsylvania, perhaps, that her sanitary condition is no worse than that of the States which have not been named and that a comparison with Massachusetts, noted the world over for its sanitary achievement and its excellent State and local government, is unfair. Even if such a plea could be supported by facts, which is doubtful, is it a worthy defense?

“Pennsylvania as a State is wealthy and prosperous; it can afford to better its sanitary condition. The cities which

have grown up within its borders entail a responsibility that may not be likely ignored. Sanitary conditions inherited from primitive days become unbearable as population grows more dense and as means for the spread of communicable disease are multiplied.

“It is, therefore, no defense for Pennsylvania to cite the backward sanitary condition of States farther East or farther West. The State is rich enough to afford good sanitation and its densely populated cities demand such sanitation as the price of their citizens’ lives. It is to be hoped that such object lessons as the calamity at Butler may have an influence towards bringing about reform.”

On page 166 of the *Municipal Journal and Engineer*, Vol. XVI, No. 4, April, 1904, appears an article entitled “Purification of Water by Ozone: A Chemical Process Requiring no After Treatment—Frees Water from Bacteria and Iron—How it is Done.” In this article Dr. Erlwein, of Berlin, speaking on this subject at the forty-third annual meeting of the German Union of Gas and Water Engineers, and describing the ozonizing apparatus in use for the purification of the water supply of Paderborn, in Germany, referring to the ozonizing plant at Martinikenfeld, says: “It has been thoroughly tested with Spree water full of cholera, typhus and other disease germs artificially reared and added to the water. The result was to prove that the ozone treatment killed all the disease germs even when in greater numbers than are present during epidemics.

“As regards the chemical effect of the ozonization of water it diminishes the oxidization degree of the water by fifteen to twenty-five per cent. and increases its content of free oxygen. The ozone reaction vanishes a few seconds after the water leaves the tower, and no taste is given to the water * * *. Ozone is not only a bactericide but frees water so perfectly from iron that it may well be used for that purpose alone * * *. The ozonization process, too, should not cause forgetfulness of the immense service which

the sand filtration of water has rendered to sanitation, in spite of the unquestionable efficacy of ozonization in killing all pathogenic bacteria, while sand filtration does nothing more than diminish their number. The ozone process must always be taken seriously into consideration where difficulties arise in large towns as regards extending already existing filter beds or making new ones, when they may need the acquisition of land at heavy expense. The ozone plant is also excellent for places where it is impossible to rely too much on the waterworks staff. * * *

“* * * There are cases, too, in which iron and organisms giving taste and smell to the water can only be removed by ozone. In short, every case must be judged independently for the determination of the most suitable system, or combination of systems, for purifying the water.”

I think it is safe to say that the various authorities which the writer has quoted, and which authorities, both European and American, are conceded to rank among the highest, bear witness to the following facts:

First.—That filtration alone can in addition to clarifying water effect purification of the same, only to a degree varying with construction, maintenance, supervision, etc., of the plant, and

Second.—That by ozonizing a previously clarified water absolute purity is obtained. Hence I cannot but express the belief that as an adjunct to any filtration system, sufficiently efficient to produce clear water, sterilization by ozone will prove to be one of the greatest blessings of this century.

(Signed) J. J. DE KINDER.



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